From:	[redacted]
To:	IPCN Enquiries Mailbox
Subject:	United Wambo Open Cut Coal Mine Project SSD 7142: Submission on issue of greenhouse gases and an Export Management Plan.
Date:	Friday, 9 August 2019 3:41:04 PM
Attachments:	ITD - NSW IPC Bylong Submission November 2018.pdf BT paper risk security.05.pdf BT paper third degree 150719.pdf What Lies Beneath 2018 fin.pdf

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To: Mr Tony Pearson
Chair
NSW Independent Planning Commission Panel
United Wambo Open Cut Coal Mine Project

Dear Mr Pearson

I write in regard to your notification that, for the United Wambo Open Cut Coal Mine Project, the Commission Panel is considering a requirement for the mine to submit an Export Management Plan confirming that the Applicant will use best endeavours to ensure coal exports will only be supplied to countries which are either signatories to the Paris Climate Change Agreement or hold similar climate policy positions.

Whilst it is a welcome step forward for NSW planning and approval processes to recognise the importance of human-induced climate change and Scope 3 greenhouse gas emissions in approving this coal mine development, the suggested condition is wholly inadequate given the rapidly accelerating impact of climate change globally.

As a result of the failure of political and corporate leaders to accept the reality of climate change, it now represents an immediate existential threat to the future of humanity, which can only be addressed by emergency action.

The rationale for that view is set out in my submission to the IPC of 7th November 2018 in relation to the Bylong Coal Mine project, copy attached and at: https://www.ipcn.nsw.gov.au/resources/pac/media/files/pac/project-submissions/2018/10/bylong-coal-project/20181108t120203/itd--nsw-ipc-bylong-submission-november-2018.pdf

In that submission, I concluded that the development of new coal mines in the current circumstances of rapidly accelerating human-induced climate change is: *"suicidal, morally and ethically bankrupt and constitutes a crime against humanity"*. The same applies to major coal mine extensions.

Even since the submission was lodged, that accelerating impact has become ever more obvious, with records continually broken for extreme weather events globally, Australia included, and mounting economic and social cost.

Global communities in the last few months are declaring the need to treat climate change as a genuine emergency, for the reasons I outlined in my submission and accompanying material. At the last count, 888 councils and states in 18 countries, covering some 206 million people had committed to this course of action. This includes the UK, France, Ireland, London, New York, Paris,

Vancouver, Sydney, Melbourne and many more.

In addition, global civil disobedience is rapidly increasing as politicians fail in their duty to seriously address climate change, notably the schoolchildren movement and organisations such as Extinction Rebellion. These join organisations such as Lock the Gate and Stop Adani, who have been fighting to stop coal development for years.

Because of the failure of governments and corporations to act, we are now faced with the likely prospect that the lower global average temperature increase of the Paris Agreement, 1.5degC, will happen by 2030. Further, it is quite likely that we will see a temperature increase by 2050 of 3degC, which would be a world of social chaos.

This is explained in a paper my colleague David Spratt and I released in May 2019, with a foreword by Admiral Chris Barrie, former head of the Australian Defence Force: "*Existential climate-related security risk – a scenario approach",* copy attached. The paper contains a simple 3degC 2050 global scenario setting out the hard-nosed practical implications. This scenario resulted in extensive discussion globally, some considering the scenario to be entirely credible, others that it was too extreme.

Accordingly we have just released a second paper: *"The Third Degree: evidence and implications for Australia of existential climate-related security risk"* copy attached. This paper explains the basis for the original scenario in more depth, and includes a detailed 3degC 2050 scenario developed by senior US national security experts in 2007.

Both papers are also available at: https://www.breakthroughonline.org.au/papers

In the light of the information which is now available on the escalating impact of climate change, both in these papers and more widely, nobody with any degree of responsibility or concern for the future of humanity, and of future generations, either in Australia or elsewhere, can seriously support the development of any new coal projects and major extensions.

Accordingly, the development of an Export Management Plan is an inappropriate response to the threat we now face from climate change.

If the Independent Planning Commission is to fulfil its Mission and Vision of: "*delivering a high level of independence, expertise and transparency --- to ensure well executed developments that benefit the people of NSW*", what is required is a straightforward statement by the IPC that no further new coal developments, whether Bylong or United Wambo, should be contemplated in NSW.

Anything less is placing the future of the NSW community in great jeopardy, which I would suggest is totally contrary to the IPC mandate.

I would be pleased to explain these conclusions further at your convenience.

Yours sincerely

Ian Dunlop
Mob: [redacted]

Gordon Kirkby
Chair
NSW Independent Planning Commission Panel
Bylong Coal Project
Level 3
201 Elizabeth St
NSW 2000

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Gordon
NSW 2072
Australia

Email: [redacted]

The Bylong Coal Project
Implications for Australian & Global Climate Change

Dear Mr Kirkby
In your consideration of the Bylong Coal Project, I draw your attention to the fact that the greatest risk to the Australian community from the development of the project has been largely ignored, namely its potential impact on local and global climate change.

Passing reference is made in the Final Assessment Report to the mine's greenhouse gas emissions. The assumption that State, National and International climate policy, let alone the overwhelming scientific consensus on the dangers the world, and particularly Australia, now face from climate change, have no bearing on the decision to allow the mine to proceed, in current circumstances is criminally negligent.

The recent Intergovernmental Panel on Climate Change (IPCC) report on the impact of 1.5°C and 2°C warming above pre-industrial levels [i] sent a stark reminder to humanity about the existential threat posed by climate change. To avoid worst outcomes, global emissions must be cut by half by 2030, and to zero by 2050. This is an unprecedented task, requiring a reduction rate of at least 7% annually; no country has achieved more than 1.5% previously. The only possible response is emergency action to transform our social, economic and financial systems.

Unfortunately the IPCC tend to underestimate the risks to which we are now exposed. This is highlighted in another recent report entitled: "*What Lies Beneath: The understatement of existential climate risk*" [ii] (copy attached) co-authored by David Spratt and myself.

This publication collates what scientists, decision-makers and other stakeholders have been saying, often behind closed doors, about the culture of failure and scientific reticence in which climate policy-making has become embedded. It is a story that must be understood if we are to have any hope of addressing the existential climate risk which humanity now faces. The report analyses why:

- Human-induced climate change is now an existential risk to human civilisation: an adverse outcome that will either annihilate intelligent life or permanently and drastically curtail its potential, unless dramatic action is taken. The bulk of climate research tends to underplay these risks, exhibiting a preference for conservative projections and scholarly reticence.
- Reports of the IPCC, including the most recent one referenced above, around which international negotiations have been based, also tend toward reticence and caution, erring on the side of "*least drama*", and downplaying the more extreme and more damaging outcomes. This is dangerously misleading with the acceleration of climate impacts globally.
- Potential climatic "*tipping points*" are a particular concern; the passing of critical thresholds which result in step changes in the climate system. Under-reporting on these issues is contributing to a "*failure of imagination*" in our response to climate change.

In the foreword, Professor Hans Joachim Schellnhuber, founder of the Potsdam Institute for Climate Impact Research, adviser to German Chancellor Angela Merkel and to Pope Francis, calls the report a "*critical overview by well-informed intellectuals who sit outside the climate-science community*", highlighting crucial insights which may lurk at the fringes of conventional policy analysis but which have a new resonance when "*the issue is the very survival of our civilisation, where conventional means of analysis may become useless*". He says: "*climate change is now reaching the end-game, where very soon humanity must*

choose between taking unprecedented action, or accepting that it has been left too late and bear the consequences".

The purpose of the report is to highlight that the crucial moment is now, to understand why that is so, and to encourage a fundamental emergency reframing of our approach to climate action. The rationale for emergency action is as follow:

- **Dangerous climate change is occurring at the 1°C temperature increase already experienced.** 2°C now represents the boundary of extremely dangerous climate change.

- **To stay below the upper 2°C temperature increase limit of the Paris Climate Agreement, global emissions would have to peak no later than 2020 and be reduced by around 7% annually thereafter**. To meet the lower 1.5°C target requires even more rapid reduction. By contrast, emissions continue to rise in line with worst case scenarios.

- **Probabilities used to define the carbon budget to stay below the Paris objectives are unrealistic.** The IPCC uses 50 to 66% chance as the norm. Not good odds for the future of humanity. Carbon budgets, and emissions reductions, should be based upon a realistic chance, at least 90%, of reaching the goals. On that basis, there is practically no carbon budget left today to stay below 2°C, let alone 1.5°C.

- **Climate inertia means that allowing continued fossil fuel investment today, such as the Bylong coal mine, with associated emission increases, risks locking-in irreversible, existential climatic outcomes.** By the time the climatic impact of these investments becomes clear, it will be too late to take action and avoid extensive stranded assets.

- **Atmospheric aerosols produced by burning coal and oil are cooling the planet by around 0.3 to 0.5°C.** As these concentrations reduce with the phase-out of fossil fuels, a commensurate one-off increase in temperature is likely, further compounding the problem of staying below warming limits.

- **IPCC scenarios still rely heavily on carbon removal from the atmosphere as a prerequisite for meeting the 1.5°C target.** The degree of dependence on such negative emissions technologies, none of which exist at scale today, is extremely dangerous, creating a false sense of security that there are easy solutions when none exist.

- **The recent IPCC summary report understates key risks in moving from 1.5°C to 2°C warming.** For example, a likely rise in climate-driven refugees, the danger of exceeding tipping points that could push the world on to an irreversible path to a "Hothouse Earth" [iii], cyrosphere risks such as Antarctic ice sheet instability and loss of the Greenland ice sheet being triggered, leading over time to multi-metre sea level increase. Exceeding 1.5°C poses huge risks both for humans and natural systems.

- **Despite three decades of intense activity by NGO's, progressive business, governments, official bodies and international organisations,** it is virtually impossible to now limit temperature increases to the lower 1.5°C limit of the Paris climate agreement, and probably to the 2°C upper limit, unless state and non-state actors across the globe unite in support of fundamental change

This is summarised in the attached short presentation.

Effective action on climate change must be raised above political infighting if the Federal and State government's oft-quoted first responsibility to ensure the security of the Australian people is to have any meaning. That security is being undermined by the refusal of successive governments to treat climate change seriously, leading to rapidly increasing economic and social costs. This is most recently evident with the current drought, which is undoubtedly being intensified by climate impact resulting to a large extent from fossil fuel combustion.

The Federal Government currently has no meaningful climate change or energy policy and the NSW State policy is little better:

- The Federal emission reduction target of 26-28% by 2030 based on 2005 levels is wholly inadequate on any fair international comparison, and far lower than required to avoid catastrophic climate outcomes

- It does not constitute policy without a means of achieving even that inadequate target. Achieving the targets will not happen without continued encouragement of low-carbon alternatives to fossil fuels; the development of new coal mines such as Bylong makes the task even harder, and is totally contradictory to Australia's commitment to the Paris Climate Agreement.

- The biggest subsidy in the energy sector, far outweighing any support to the renewable energy industry, is the lack of a carbon price to account for the externalities of fossil-fuel use (ie pollution, climate damage and health impacts). Removal of that subsidy by imposing a carbon price, which is inevitable, does not seem to have featured in the KEPCO considerations, further adding to the risk of the mine becoming a stranded asset, with the serious damage to local communities this implies.

- Rather than being a minor player in the global emission stakes, with our domestic emissions being only 1.3% of the global total as the Federal government continually argues, Australia is the world's sixth largest carbon polluter when our exports are included, as they must be given the climate risks we now face; shortly to become the fourth largest polluter as our LNG exports increase. What Australia does seriously impacts the global climate. The Bylong mine will only make matters worse.

- The irony is that we have far better prospects of prospering economically and socially in a low-carbon world by expanding renewable energy use than by maintaining or expanding the fossil fuel status quo with developments such as Bylong; in the process avoiding much damage to our agricultural and water resources and the communities which depend upon them.

- The Bylong Benefit Cost Analysis (BCA) is seriously deficient in that it takes a narrow and optimistic view of the benefits of coal mine development and completely ignores the far greater costs imposed by the externalities of coal use, both in local environmental and health impact, and more importantly, the climate impact arising from coal combustion. This reflects a fundamental weakness in Australian environmental legislation which does not take a systemic, holistic, approach to assessing the full impact of such developments.

- Arguments that developments such as Bylong are essential to assist in poverty alleviation and encourage economic growth in Asia, and that if we do not supply coal others will, are not valid in a world facing an immediate existential threat from increasing use of fossil fuels, particularly coal.

The critical task now for Australia, and the world, is to cut carbon emissions far more rapidly than current Paris commitments, exiting the fossil fuel era and accelerating the introduction of low carbon alternatives, coupled with demand reduction initiatives. To allow the development of new coal mines such as Bylong in these circumstances is suicidal, morally and ethically bankrupt and constitutes a crime against humanity. I urge your panel to recommend against the Bylong Coal Project development in the strongest possible terms.

Unfortunately I have not been able to participate in recent public hearings due to absence overseas. However I would be pleased to discuss these issues with the panel at your convenience.

Yours sincerely

Ian T Dunlop [redacted] **Mob:** [redacted]

Author

Ian Dunlop has wide experience in energy resources, infrastructure, and international business, for many years on the international staff of Royal Dutch Shell. He has worked at senior level in oil, gas and coal exploration and production, in scenario and long-term energy planning, competition reform and privatization.

He chaired the Australian Coal Associations in 1987-88. From 1998-2000 he chaired the Australian Greenhouse Office Experts Group on Emissions Trading which developed the first emissions trading system design for Australia. From 1997 to 2001 he was CEO of the Australian Institute of Company Directors.

An engineer from the University of Cambridge (UK), MA Mechanical Sciences, he is a Fellow of the Australian Institute of Company Directors, the Australasian Institute of Mining and Metallurgy and the Energy Institute (UK), and a Member of the Society of Petroleum Engineers of AIME (USA).

Ian is a member of the Board of the ARC Centre of Excellence for Climate Extremes based at UNSW, and a member of the Club of Rome.

References

[i] Global Warming of 1.5°C – Summary for Policymakers, IPCC, 8th October 2018: http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

[ii] What Lies Beneath: The Understatement of Existential Climate Risk, Spratt & Dunlop, August 2018: https://www.breakthroughonline.org.au

[iii] Trajectories of the Earth System in the Anthropocene, Steffen, Rockstrom, Schellnhuber et al, PNAS July 2018: http://www.pnas.org/content/115/33/8252

(Note: Hard copy of reports being forwarded by mail)

[redacted]

POLICY PAPER

Written By:
David Spratt
& Ian Dunlop

Foreword By:
Admiral Chris Barrie
AC RAN Retired

Existential climate-related security risk:

A scenario approach

MAY 2019

Breakthrough - National Centre for Climate Restoration | breakthroughonline.org.au

THE AUTHORS

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David Spratt is a Research Director for Breakthrough National Centre for Climate Restoration, Melbourne, and co-author of *Climate Code Red: The case for emergency action.*

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Ian T. Dunlop is a member of the Club of Rome. Formerly an international oil, gas and coal industry executive, chairman of the Australian Coal Association, chief executive of the Australian Institute of Company Directors, and chair of the Australian Greenhouse Office Experts Group on Emissions Trading 1998-2000.

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FOREWORD

Admiral Chris Barrie, AC RAN Retired

In 2017-18, the Australian Senate inquired into the implications of climate change for Australia's national security. The Inquiry found that climate change is "a current and existential national security risk", one that "threatens the premature extinction of Earth-originating intelligent life or the permanent and drastic destruction of its potential for desirable future development".

I told the Inquiry that, after nuclear war, human-induced global warming is the greatest threat to human life on the planet. Today's 7.5 billion human beings are already the most predatory species that ever existed, yet the global population has yet to peak and may reach 10 billion people, with dire implications absent a fundamental change in human behaviour.

This policy paper looks at the existential climate-related security risk through a scenario set thirty years into the future. David Spratt and Ian Dunlop have laid bare the unvarnished truth about the desperate situation humans, and our planet, are in, painting a disturbing picture of the real possibility that human life on earth may be on the way to extinction, in the most horrible way.

In Australia recently we have seen and heard signals about the growing realisation of the seriousness of our plight. For example, young women speak of their decisions to not have children, and climate scientists admitting to depression as they consider the "inevitable" nature of a doomsday future and turn towards thinking more about family and relocation to "safer" places, rather than working on more research.

Stronger signals still are coming from increasing civil disobedience, for example over the opening up of the Galilee Basin coal deposits and deepwater oil exploration in the Great Australian Bight, with the suicidal increase in carbon emissions they imply. And the outrage of schoolchildren over their parent's irresponsibility in refusing to act on climate change.

As my colleague Professor Will Steffen has said of the climate challenge: "It's not a technological or a scientific problem, it's a question of humanity's socio-political values… We need a social tipping point that flips our thinking before we reach a tipping point in the climate system."

A doomsday future is not inevitable! But without immediate drastic action our prospects are poor. We must act collectively. We need strong, determined leadership in government, in business and in our communities to ensure a sustainable future for humankind.

In particular, our intelligence and security services have a vital role to play, and a fiduciary responsibility, in accepting this existential climate threat, and the need for a fundamentally different approach to its risk management, as central to their considerations and their advice to government. The implications far outweigh conventional geopolitical threats.

I commend this policy paper to you.

Admiral Chris Barrie, AC RAN Retired, is Honorary Professor, Strategic & Defence Studies Centre, Coral Bell School of Asia Pacific Affairs, Australian National University, Canberra. He is a member of the Global Military Advisory Council on Climate Change and was Chief of the Australian Defence Force from 1998 to 2002.

OVERVIEW

- Analysis of climate-related security threats depends significantly on understanding the strengths and limitations of climate science projections. Much scientific knowledge produced for climate policy-making is conservative and reticent.
- Climate change now represents a near- to mid-term existential threat to human civilisation. But this is not inevitable. A new approach to climate-related security risk-management is thus required, giving particular attention to the high-end and difficult-to-quantify "fat-tail" possibilities, in order to avoid such an outcome.
- This may be most effectively explored by scenario analysis. A 2050 scenario of the high-end risks is outlined in which accelerating climate- change impacts pose large negative consequences to humanity which might not be undone for centuries.
- To reduce or avoid such risks and to sustain human civilisation, it is essential to build a zero-emissions industrial system very quickly. This requires the global mobilisation of resources on an emergency basis, akin to a wartime level of response.

INTRODUCTION

> *The true worst-case scenario might be one where we don't venture out from our safe harbors of knowledge to explore the more treacherous shores of uncertainty.*
>
> — Dr Gavin Schmidt, Director of the NASA Goddard Institute for Space Studies[1]

Climate change intersects with pre-existing national security risks to function as a threat multiplier and accelerant to instability, contributing to escalating cycles of humanitarian and socio-political crises, conflict and forced migration.

Climate-change impacts on food and water systems, declining crop yields and rising food prices driven by drought, wildfire and harvest failures have already become catalysts for social breakdown and conflict across the Middle East, the Maghreb and the Sahel, contributing to the European migration crisis.

Understanding and foreseeing such events depends crucially on an appreciation of the real strengths and limitations of climate-science projections, and the application of risk-management frameworks which differ fundamentally from conventional practice.

[1] Schmidt, G. 2018. "The best case for worst case scenarios", *Real Climate*, 19 February 2019, accessed 18 March 2019, http://www.realclimate.org/index.php/archives/2019/02/the-best-case-for-worst-case-scenarios.

SCIENTIFIC RETICENCE

Climate scientists may err on the side of "least drama", whose causes may include adherence to the scientific norms of restraint, objectivity and skepticism, and may underpredict or down-play future climate changes.[2] In 2007, security analysts warned that, in the two previous decades, scientific predictions in the climate-change arena had consistently under-estimated the severity of what actually transpired.[3]

This problem persists, notably in the work of the Intergovernmental Panel on Climate Change (IPCC), whose *Assessment Reports* exhibit a one-sided reliance on general climate models, which incorporate important climate processes, but do not include all of the processes that can contribute to system feedbacks, compound extreme events, and abrupt and/or irreversible changes.[4]

Other forms of knowledge are downplayed, including paleoclimatology, expert advice, and semi-empirical models. IPCC reports present detailed, quantified, complex modelling results, but then briefly note more severe, non- linear, system-change possibilities in a descriptive, non-quantified form. Because policymakers and the media are often drawn to headline numbers, this approach results in less attention being given to the most devastating, difficult-to-quantify outcomes.

In one example, the IPCC's *Fifth Assessment Report* in 2014 projected a sea-level rise of 0.55-0.82 metre by 2100, but said "levels above the likely range cannot be reliably evaluated". By way of comparison, the higher of two US Department of Defence scenarios is a two-metre rise by 2100, and the "extreme" scenario developed by a number of US government agencies is 2.5 metres by 2100.[5]

Another example is the recent IPCC 1.5˚C report, which projected that warming would continue at the current rate of ~0.2˚C per decade and reach the 1.5˚C mark around 2040. However the 1.5˚C boundary is likely to be passed in half that time, around 2030, and the 2˚C boundary around 2045, due to accelerating anthropogenic emissions, decreased aerosol loading and changing ocean circulation conditions.[6]

[2] Brysse, K., et al. 2013, "Climate change prediction: Erring on the side of least drama?", *Global Environmental Change,* 23(1), 327-337.

[3] Campbell, K.M., et al. 2007. *The Age of Consequences: The foreign policy and national security implications of global climate change*, Washington DC, Centre for Strategic and International Studies /Center for New American Security, 9.

[4] Wuebbles, D J., et al. 2017. *Climate Science Special Report: Fourth National Climate Assessment, Volume I,* Washington DC, US Global Change Research Program, 411.

[5] Thieler, E.R. and Zervas, C. 2017. *Global and Regional Sea Level Rise Scenarios for the United States*, NOAA Technical Report NOS CO-OPS 083, Silver Spring MA, NOAA/NOS Center for Operational Oceanographic Products and Services.

[6] Xu, Y., et al. 2018. "Global warming will happen faster than we think", *Nature*, 564 (7734), 30-32; Henley, B J., and King. A.D. 2017. "Trajectories toward the 1.5˚C Paris target: Modulation by the Interdecadal Pacific Oscillation", *Geophysical Research Letters*, 44(9), 4256-62; Jacob, D., et al. 2018. "Climate Impacts in Europe Under +1.5˚C", Global Warming', *Earth's Future*, 6(2), 264-285.

EXISTENTIAL RISK

An existential risk to civilisation is one posing permanent large negative consequences to humanity which may never be undone, either annihilating intelligent life or permanently and drastically curtailing its potential.

With the commitments by nations to the 2015 *Paris Agreement*, the current path of warming is 3˚C or more by 2100. But this figure does not include "long-term" carbon-cycle feedbacks, which are materially relevant now and in the near future due to the unprecedented rate at which human activity is perturbing the climate system. Taking these into account, the Paris path would lead to around 5˚C of warming by 2100.[7]

Scientists warn that warming of 4˚C is incompatible with an organised global community, is devastating to the majority of ecosystems, and has a high probability of not being stable. The World Bank says it may be "beyond adaptation".[8] But an existential threat may also exist for many peoples and regions at a significantly lower level of warming. In 2017, 3˚C of warming was categorised as "catastrophic" with a warning that, on a path of unchecked emissions, low-probability, high-impact warming could be catastrophic by 2050.[9]

The Emeritus Director of the Potsdam Institute, Prof. Hans Joachim Schellnhuber, warns that "climate change is now reaching the end-game, where very soon humanity must choose between taking unprecedented action, or accepting that it has been left too late and bear the consequences."[10] He says that if we continue down the present path "there is a very big risk that we will just end our civilisation. The human species will survive somehow but we will destroy almost everything we have built up over the last two thousand years."[11]

Unfortunately, conventional risk and probability analysis becomes useless in these circumstances because it excludes the full implications of outlier events and possibilities lurking at the fringes.[12]

Prudent risk-management means a tough, objective look at the real risks to which we are exposed, especially at those "fat-tail" events, which may have consequences that are damaging beyond quantification, and threaten the survival of human civilisation.

Global warming projections display a "fat-tailed" distribution with a greater likelihood of warming that is well in excess of the average amount of warming predicted by climate models, and are of a higher probability than would be expected under typical statistical assumptions. More importantly, the risk lies disproportionately in the "fat-tail" outcomes, as illustrated in Figure 1.

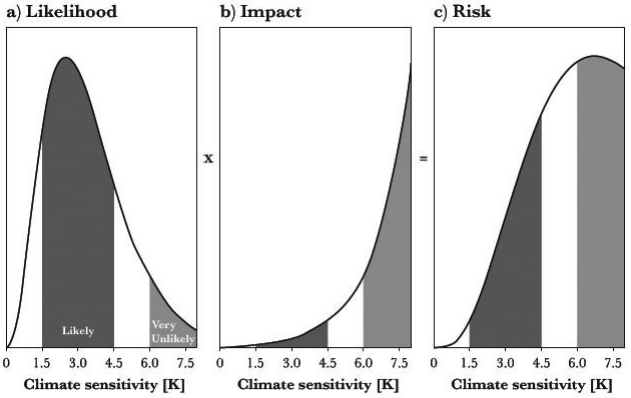

Figure 1. Schema of climate-related risk. (a) Event likelihood and (b) Impacts produce (c) Risk. Lower likelihood events at the high end of the probability distribution have the highest risk (Credit: RT Sutton/E Hawkins).

This is a particular concern with potential climate tipping-points — passing critical thresholds which result in step changes in the climate system that will be irreversible on human timescales — such as the polar ice sheets (and hence sea levels), permafrost and other carbon stores, where the impacts of global warming are non-linear and difficult to model with current scientific knowledge.

Recently, attention has been given to a "hothouse Earth" scenario, in which system feedbacks and their mutual interaction could drive the Earth System climate to a point of no return, whereby further warming would become self-sustaining. This "hothouse Earth" planetary threshold could exist at a temperature rise as low as 2˚C, possibly even lower.[13]

[7] Reilly, J., et al. 2015. *Energy and Climate Outlook: Perspectives from 2015*, Cambridge MA, MIT Program on the Science and Policy of Global Change.

[8] Spratt, D., and Dunlop, I. 2018. *What Lies Beneath: The understatement of existential climate risk*, Melbourne, Breakthrough National Centre for Climate Restoration, 14.

[9] Xu, Y., and Ramanathan, V. 2017. "Well below 2 ˚C: Mitigation strategies for avoiding dangerous to catastrophic climate changes", *Proceedings of the National Academy of Sciences,* 114(39), 10315-10323.

[10] Schellnhuber, H.J. 2018. "Foreword", in Spratt, D., and Dunlop, I. 2018, *op. cit*, 3.

[11] Breeze, N. 2018. "It's non-linearity, stupid", *The Ecologist*, 3 January 2019, accessed 18 March 2019, https://theecologist.org/2019/jan/03/its-nonlinearity-stupid

[12] Schellnhuber, H.J. 2018, *op. cit.*, 3.

[13] Steffen, W., et al. 2018. "Trajectories of the Earth System in the Anthropocene", *Proceedings of the National Academy of Sciences*, 115(33), 8252-8259.

EXISTENTIAL RISK MANAGEMENT

Because the consequences are so severe — perhaps the end of human global civilisation as we know it — "even for an honest, truth-seeking, and well-intentioned investigator it is difficult to think and act rationally in regard to… existential risks".[14] Particular issues arise: What are the plausible worst cases? And how can one tell? Are scientists self-censoring to avoid talking about extremely unpleasant outcomes? Do scientists avoid talking about the most alarming cases to motivate engagement?[15]

Analysis of climate-related security threats in an era of existential risk must have a clear focus on the extremely serious outcomes that fall outside the human experience of the last thousand years. These "fat-tail" outcomes have probabilities that are far higher than is generally understood.

Traditionally, risk is assessed as the product of probability and damage. But when the damage is beyond quantification, this process breaks down. With existential risks, learning from mistakes is not an option, and we cannot necessarily rely on the institutions, moral norms, or social attitudes developed from our experience with managing other types of risk.

What is needed now is an approach to risk management which is fundamentally different from conventional practice. It would focus on the high-end, unprecedented *possibilities,* instead of assessing middle-of-the-road *probabilities* on the basis of historic experience.

Scenario planning can overcome such obstacles, provided it is used to explore the *unprecedented possibilities,* and not simply act as a type of conventional sensitivity analysis, as is often the case in current practice. Properly applied, it can provide a framework that enables managers to better handle these critical uncertainties, avoid dangerous "group think" and provide flexible rather than unidimensional strategies, thereby potentially improving the quality of decisions in this vital arena.[16]

Existential risks require a normative view of the targets required to avoid catastrophic consequences, based on the latest science within a qualitative, moral framework. Action is then determined by the imperative to achieve the target. It requires policy that is integrated across national, regional and global boundaries, and which recognises that issues such as climate, energy, the ecological crisis and resources overuse are inextricably linked and cannot be treated in separate "silos", as at present.

In Prof. Schellnhuber's words: "We must never forget that we are in a unique situation with no precise historic analogue. The level of greenhouse gases in the atmosphere is now greater, and the Earth warmer, than human beings have ever experienced. And there are almost eight billion of us now living on this planet. So calculating probabilities makes little sense in the most critical instances… Rather, we should identify *possibilities,* that is, potential developments in the planetary makeup that are consistent with the initial and boundary conditions, the processes and the drivers we know."[17]

In this spirit, we sketch a 2050 scenario. We emphasise that this is a scenario at the high-end of the range of possibilities. It is a scenario, a way of thinking about the potential impacts that could occur, not a scientific projection of what will occur. The odds of a civilization-ending outcome are less than the odds of any single catastrophe, but the consequences of that outcome are so immense and horrible that it is important to consider what it would mean, and understand that we must take every possible step to avoid it.

[14] Bostrom, N., and Cirkovic, M.M. 2008. *Global Catastrophic Risks*, Oxford, Oxford University Press, 9.
[15] Schmidt, G. 2019, *op. cit.*
[16] Meißner, P. 2013. "The benefits of scenario-based planning" in Schwenker, B. and Wulf, T. (eds.) *Scenario-based Strategic Planning*, Weisbaden, Springer Fachmedien Weisbaden.
[17] Schellnhuber, H.J. 2018, *op. cit.,* 3.

A 2050 SCENARIO

2020–2030: Policy-makers fail to act on evidence that the current *Paris Agreement* path — in which global human-caused greenhouse emissions do not peak until 2030 — will lock in at least 3˚C of warming. The case for a global, climate-emergency mobilisation of labour and resources to build a zero-emission economy and carbon drawdown in order to have a realistic chance of keeping warming well below 2˚C is politely ignored. As projected by Xu and Ramanathan, by 2030 carbon dioxide levels have reached 437 parts per million — which is unprecedented in the last 20 million years — and warming reaches 1.6˚C.[18]

2030–2050: Emissions peak in 2030, and start to fall consistent with an 80 percent reduction in fossil-fuel energy intensity by 2100 compared to 2010 energy intensity. This leads to warming of 2.4˚C by 2050, consistent with the Xu and Ramanathan "baseline-fast" scenario.[19] However, another 0.6˚C of warming occurs — taking the total to 3˚C by 2050 — due to the activation of a number of carbon-cycle feedbacks and higher levels of ice albedo and cloud feedbacks than current models assume.

[It should be noted that this is far from an extreme scenario: the low-probability, high-impact warming (five percent probability) can exceed 3.5–4˚C by 2050 in the Xu and Ramanathan scheme.]

2050: By 2050, there is broad scientific acceptance that system tipping-points for the West Antarctic Ice Sheet and a sea-ice-free Arctic summer were passed well before 1.5˚C of warming, for the Greenland Ice Sheet well before 2˚C, and for widespread permafrost loss and large-scale Amazon drought and dieback by 2.5˚C. The "hothouse Earth" scenario has been realised, and Earth is headed for another degree or more of warming, especially since human greenhouse emissions are still significant.[20]

While sea levels have risen 0.5 metres by 2050, the increase may be 2–3 metres by 2100, and it is understood from historical analogues that seas may eventually rise by more than 25 metres.

Thirty-five percent of the global land area, and 55 percent of the global population, are subject to more than 20 days a year of lethal heat conditions, beyond the threshold of human survivability.

The destabilisation of the Jet Stream has very significantly affected the intensity and geographical distribution of the Asian and West African monsoons and, together with the further slowing of the Gulf Stream, is impinging on life support systems in Europe. North America suffers from devastating weather extremes including wildfires, heatwaves, drought and inundation. The summer monsoons in China have failed, and water flows into the great rivers of Asia are severely reduced by the loss of more than one-third of the Himalayan ice sheet. Glacial loss reaches 70 percent in the Andes, and rainfall in Mexico and central America falls by half. Semi-permanent El Nino conditions prevail.

Aridification emerges over more than 30 percent of the world's land surface. Desertification is severe in southern Africa, the southern Mediterranean, west Asia, the Middle East, inland Australia and across the south-western United States.

Impacts: A number of ecosystems collapse, including coral reef systems, the Amazon rainforest and in the Arctic.

Some poorer nations and regions, which lack capacity to provide artificially-cooled environments for their populations, become unviable. Deadly heat conditions persist for more than 100 days per year in West Africa, tropical South America, the Middle East and South-East Asia, contributing to more than a billion people being displaced from the tropical zone.

Water availability decreases sharply in the most affected regions at lower latitudes (dry tropics and subtropics), affecting about two billion people worldwide. Agriculture becomes nonviable in the dry subtropics.

[18] Xu, Y., and Ramanathan, V. 2017, *op. cit*.
[19] Xu, Y., and Ramanathan, V. 2017, *op. cit*.
[20] Data for this scenario is drawn from a wide range of sources, including: Xu, Y. and Ramanathan, V. 2017, *op. cit*.; Campbell, K.M., et al. 2007, *op cit.*; Mora, C., et al. 2017. "Global risk of deadly heat", *Nature Climate Change*, 7, 501-506; Lynas, M. 2007. *Six Degrees: Our future on a hotter planet*, London, Fourth Estate; Wallace-Wells, D. 2019. *The Uninhabitable Earth: Life after warming*, New York, Duggan Books.

Most regions in the world see a significant drop in food production and increasing numbers of extreme weather events, including heat waves, floods and storms. Food production is inadequate to feed the global population and food prices skyrocket, as a consequence of a one-fifth decline in crop yields, a decline in the nutrition content of food crops, a catastrophic decline in insect populations, desertification, monsoon failure and chronic water shortages, and conditions too hot for human habitation in significant food-growing regions.

The lower reaches of the agriculturally-important river deltas such as the Mekong, Ganges and Nile are inundated, and significant sectors of some of the world's most populous cities — including Chennai, Mumbai, Jakarta, Guangzhou, Tianjin, Hong Kong, Ho Chi Minh City, Shanghai, Lagos, Bangkok and Manila — are abandoned. Some small islands become uninhabitable. Ten percent of Bangladesh is inundated, displacing 15 million people.

Even for 2˚C of warming, more than a billion people may need to be relocated and In high-end scenarios, the scale of destruction is beyond our capacity to model, with a high likelihood of human civilisation coming to an end.[21]

National security consequences: For pragmatic reasons associated with providing only a sketch of this scenario, we take the conclusion of the *Age of Consequences* 'Severe' 3˚C scenario developed by a group of senior US national-security figures in 2007 as appropriate for our scenario too:

> Massive nonlinear events in the global environment give rise to *massive nonlinear societal events*. In this scenario, nations around the world will be *overwhelmed by the scale of change* and pernicious challenges, such as pandemic disease. The internal cohesion of nations will be under great stress, including in the United States, both as a result of a dramatic rise in migration and changes in agricultural patterns and water availability. The flooding of coastal communities around the world, especially in the Netherlands, the United States, South Asia, and China, has the potential to *challenge regional and even national identities*. Armed conflict between nations over resources, such as the Nile and its tributaries, is likely and nuclear war is possible. The social consequences range from increased religious fervor to *outright chaos*. In this scenario, climate change provokes *a permanent shift in the relationship of humankind to nature*'.[22] (emphasis added)

[21] Wariaro, V., et al. 2018. *Global Catastrophic Risks 2018*, Stockholm, Global Challenges Foundation, 24.

[22] Campbell, K.M., et al. 2007, *op. cit.*, 9.

DISCUSSION

This scenario provides a glimpse into a world of "outright chaos" on a path to the end of human civilisation and modern society as we have known it, in which the challenges to global security are simply overwhelming and political panic becomes the norm.

Yet the world is currently completely unprepared to envisage, and even less deal with, the consequences of catastrophic climate change.[23]

What can be done to avoid such a probable but catastrophic future? It is clear from our preliminary scenario that dramatic action is required this decade if the "hothouse Earth" scenario is to be avoided. To reduce this risk and protect human civilisation, a massive global mobilisation of resources is needed in the coming decade to build a zero-emissions industrial system and set in train the restoration of a safe climate. This would be akin in scale to the World War II emergency mobilisation.

There is an increasing awareness that such a response is now necessary. Prof. Kevin Anderson makes the case for a Marshall Plan-style construction of zero-carbon-dioxide energy supply and major electrification to build a zero-carbon industrial strategy by "a shift in productive capacity of society akin to that in World War II".[24] Others have warned that "only a drastic, economy-wide makeover within the next decade, consistent with limiting warming to 1.5˚C", would avoid the transition of the Earth System to the Pliocene-like conditions that prevailed 3-3 3 million years ago, when temperatures were ~3˚C and sea levels 25 metres higher.[25] It should be noted here that the 1.5˚ goal is not safe for a number of Earth System elements, including Arctic sea-ice, West Antarctica and coral reefs.

The national security sector has unrivalled experience and capacity in such mobilisation, and can play a unique role in its development and implementation, as well as educating policymakers of the existential security risks in failing to do so.

POLICY RECOMMENDATIONS

- Recognise the limitations of policy-relevant climate change research which may exhibit scientific reticence.
- Adopt a scenario approach giving specific attention to high-end warming possibilities in understanding medium-range (mid-century) climate and security risks, particularly because of the existential implications.
- Give analytical focus to the role of near-term action as a determinant in preventing planetary and human systems reaching a "point of no return" by mid-century, in which the prospect of a largely uninhabitable Earth leads to the breakdown of nations and the international order.
- Urgently examine the role that the national security sector can play in providing leadership and capacity for a near-term, society-wide, emergency mobilisation of labour and resources, of a scale unprecedented in peacetime, to build a zero-emissions industrial system and draw down carbon to protect human civilisation.

[23] Ism, C., et al. 2017. *Global Catastrophic Risks 2017*, Stockholm, Global Challenges Foundation, 35.

[24] Anderson, K. 2019. 'Climate's holy trinity: how cogency, tenacity & courage could yet deliver on our Paris 2˚C commitment', Presentation to Oxford Climate Society, 24 January 2019, accessed 18 March 2019, https://www.youtube.com/watch?v=7BZFvc-ZOa8.

[25] Burke, K.D. et al., 2018. 'Pliocene and Eocene provide best analogs for near-future climates', *Proceedings of the National Academy of Sciences*, 115 (52), 13288-13293.


BREAK
THROUGH

DISCUSSION PAPER

Written By:
David Spratt
& Ian Dunlop

The third degree:

Evidence and implications for Australia of existential climate-related security risk

JULY 2019

Breakthrough - National Centre for Climate Restoration | breakthroughonline.org.au

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OVERVIEW

- Since the Paris climate conference in 2015, much time has been spent talking about and researching 1.5˚C to 2˚C of climate warming. But there has been relatively little focus on where the climate system is actually heading, given the lack of political commitment to climate action on a global scale: which is 3˚C of warming, and possibly much more.
- In May 2019, Breakthrough published a policy paper *Existential Climate-related Security Risk: A scenario approach*, which included a brief 3˚C scenario. Understanding scenarios is important because of the role they can play in "thinking the unthinkable", sensitizing and broadening mindsets to critical global developments, especially the unexpected, and adjusting strategy accordingly. Scenario planning does not forecast, predict or express preferences for the future; rather it is story-telling, painting internally-consistent pictures of alternative worlds which might emerge, given certain assumptions that are credible in the light of both known and lesser known factors.
- This paper provides detailed supporting evidence for the brief 3°C scenario. Some contentious aspects are explored, including the possibility that perhaps a billion people could be displaced by 3˚C or warming, that some regions may become too hot for human habitation for part of the year, and that critical thresholds, consistent with the "Hothouse Earth" scenario, may be passed.
- To complement this picture, a 3˚C scenario developed in 2007 by US national security analysts is reproduced. Its conclusions do not mince words. This scenario has proven prescient in foreseeing some of the major socio-political events that have already emerged in the 12 years since its publication. Understanding what 3˚C of warming really means should be a great motivator for climate emergency action.
- The first priority of any government is to protect its people. Climate change now represents the greatest threat to that security, far outweighing conventional geopolitical threats.
- Likewise, company boards have a fiduciary responsibility to ensure the viability of their organisations, and manage the threats they face, in the interests of shareholders, customers and community.
- Yet the "Official Future" in Australia for the last two decades, subscribed to by the majority of political and corporate leaders, has been, and remains, climate denial and predatory delay.
- Because of this complacent, group-think leadership failure, the Australian community is totally unprepared for the climate impacts which are already causing havoc across the continent, and which will escalate. The threat is not new, having been foreshadowed by the scientific community for decades. In this context, such attitudes represent nothing less than criminal negligence by our political and corporate incumbency.
- Holistic scenario planning on the real implications of climate change for Australia, encompassing the full range of possible futures, must be initiated as a matter of extreme urgency. We must rapidly rethink our "Official Future" before events move beyond our ability to influence outcomes. From now on policy must protect the future from the past, not the past from the future.
- To gain community support for the massive economic and social changes ahead, the outcomes of such analysis must become normalised in our thinking, socialised in everyday discussion, and become the basis for planning and action.
- Now is the time for our new Parliament, and corporate leaders, to change direction and demonstrate they have the wisdom and leadership the Australian community deserve.

"From now on policy must protect the future from the past, not the past from the future."

INTRODUCTION

Since the Paris climate conference in 2015, much time has been devoted to scenarios for 1.5˚C to 2˚C of climate warming. That's not surprising, because limiting warming to the range of 1.5–2˚C was the Paris goal, and there has since been the 2018 special IPCC report on 1.5˚C.

What hasn't been spelt out clearly is that 1.5˚C is not a good outcome: it would mean coral systems reduced to fragments, a multi-metre sea-level rise on the way, Pacific nations drowned, more lethal extreme weather, and glaciers in Antarctica passed their tipping points, just for starters.

But there is another problem about the recent discussion: there has been relatively little focus on where the climate system is actually heading, given the lack of political commitment to climate action on a global scale. And that is warming of 3˚C, and possibly much more.

Understanding what 3˚C of warming really means should be a great motivator for climate emergency action. But much of the political apparatus, the business sector and the community don't have a good understanding of the third degree.

In May 2019, Breakthrough published a policy paper *Existential Climate-related Security Risk: A scenario approach*, which received a large amount of media coverage. This included the major US network sites, plus CNN and Al Jazeera, magazines such as *New Scientist* and *GQ,* newspapers including *The Guardian* and *The Independent*, sites such as Vox, many radio interviews, and significant coverage in Europe, especially in Germany and Scandinavia. It was far more engagement that we possibly imagined when the paper was released, because we thought that there wasn't all that much new in the story of a 3˚C-warmer world.

As far back as 2007, the *Age of Consequences* report from US national security experts had painted a grim picture of that future.[1] Yet it seems the story was little understood.

The Breakthrough paper argued that analysis of climate-related security threats depends significantly on understanding the strengths and limitations of climate science projections, but much scientific knowledge produced for climate policy-making is conservative and reticent, as discussed in the 2018 Breakthrough report, *What Lies Beneath*.[2]

When properly considered, climate change now represents a near- to mid-term existential threat to human civilisation. However, this is not inevitable. A new approach to climate-related security risk management is required, giving particular attention to the high-end and difficult-to-quantify "fat-tail" possibilities, in order to avoid such an outcome.

This may be most effectively explored by scenario analysis. In the policy paper, a brief outline of a 2050 scenario of 3˚C of warming and a 0.5 metre sea level rise is explored in order to illustrate the high-end risks, in which accelerating climate-change impacts pose large negative consequences to humanity which might not be undone for centuries.

To reduce or avoid such risks and to sustain human civilisation, it is essential to build a zero-emissions industrial system very quickly. This requires the global mobilisation of resources on an emergency basis, akin to a wartime level of response.

This followup discussion paper provides detailed background to that scenario by reproducing it, now annotated with footnotes to explain the basis and sources for the analysis.

As well, we reproduce here the 3˚C scenario from *The Age of Consequences* analysis. This adds new perspectives to the brief Breakthrough scenario.

There should be clarity about the term "existential threat" used in the Breakthrough policy paper. Despite some over-the-top media coverage when it was released, the paper does not talk about human extinction in any shape or form, nor is it implied. In fact the scenario discusses the high numbers of people (billions) who will be affected one way or another, hardly circumstances consistent with a human species extinction event.

[1] Campbell, K.M, et al., 2007, *The Age of Consequences: The foreign policy and national security implications of global climate change*, Centre for Strategic and International Studies and Centre for New American Security, Washington.

[2] Spratt, D, & Dunlop, I 2018, *What Lies Beneath: The understatement of existential climate risk*, Breakthrough National Centre for Climate Restoration, Melbourne.

As discussed in the paper, the term "existential" threat or risk is applied to human *civilisation*, not humans as a *species*, consistent with the definition of the term as including events which would "permanently and drastically curtailing its potential", in this case human civilisation/culture. This is consistent with Prof. Hans Joachim Schellnhuber's statement that if we continue down the present path "there is a very big risk that we will just *end our civilisation*. The human species will survive somehow but we will destroy almost everything we have built up over the last two thousand years" (emphasis added).[3]

There were also claims that the paper is exaggerated and alarmist. Any scenario is, by its nature, somewhat speculative. Interestingly, that same criticism did not apply when the UN Secretary General António Guterres recently said: "So we are losing the race, climate change is running faster than we are, and we need to sound the alarm, this is an emergency, this is a climate crisis and we need to act now. Unfortunately in politics, there is always a huge trend to keep the status quo. The problem is that the status quo is a *suicide*" (emphasis added).[4] UNFCCC Head, Patricia Espinoza, re-iterated the call for emergency action at the recent Bonn climate discussions.[5]

Published research suggests that life in Australia would be turned upside down due to severe climate impacts if the world were to warm by 3°C, including more deaths from extreme heat waves,[6] the need to retreat from low-lying coastal areas, severe impacts on food production, including in the Murray-Darling Basin, the loss of the Great Barrier Reef, the drying of much of the sub-tropical zone, and much more.

The impacts will be even more severe in Australia's neighbourhood, the Indo-Pacific region, where the economic capacity to adapt is lower. Significant areas will be inundated as sea levels rise and some smaller countries will drown, hundreds of millions of people are likely to be displaced for one reason or another, and there will be severe water crises in some of the most populous countries — including China, India and Pakistan. States will fail.

Yet that is precisely the path we are on now, even taking the *Paris Agreement* commitments into account. In fact, warming could be a good bit higher that 3°C. This suggests that as a matter of priority comprehensive scenarios should be developed for Australia and its near region so that Australian policy-makers are well-informed about the fateful choices they are now making.

[3] Breeze, N, 2018, "It's non-linearity, stupid", *The Ecologist*, 3 January 2019.

[4] Pyper, J, 2019, "UN Chief Guterres: The status quo on climate policy 'is a suicide'", *Greentechmedia*, 7 June 2019,

[5] UNFCCC, 2019, "UN Climate Chief Urges Action on Climate Emergency", United Nations Climate Change, 18 June 2019, https://unfccc.int/news/un-climate-chief-urges-action-on-climate-emergency.

[6] Lloyd, S, 2019, "Temperature rises will make Brisbane a "difficult place to live' within 30 years, report finds", *ABC News*, 22 June 2019.

UNDERSTANDING SCENARIOS

As the complexity of the issues facing business, government and society mount, scenario planning has become an increasingly popular technique. It is rare to find a policy or economic report these days which does not claim to incorporate some form of scenario analysis.

The technique, properly used, is powerful, but sadly the term has become somewhat devalued and much of the work that purports to be scenario analysis represents little more than sensitivities around some conventional strategic plan. That is the case with climate change policy, both in Australia and globally.

Scenario planning had its genesis in the early days of the Cold War when futurist Herman Kahn and colleagues at the Rand Corporation developed the technique to "think the unthinkable" in regard to possible outcomes of nuclear deterrence. It was subsequently adopted by business, particularly by Royal Dutch Shell, to sensitize and broaden mindsets to critical global developments, especially the unexpected, and to adjust corporate strategy accordingly.

Scenarios are coherent, credible stories about alternative futures. They are created around a synthesis of multiple, wide-ranging, perspectives on a particular problem, rather than detailed development of a single viewpoint. Scenario planning does not forecast, predict or express preferences for the future; rather the story-telling paints internally-consistent pictures of alternative worlds which might emerge given certain assumptions, that are credible in the light of both known and lesser known factors.

Strategy is then assessed against each possible future. Some elements of strategy will be common under all scenarios, but others will differ markedly; the final strategic choice being made in the light of the organization's preferences, but with a better understanding of the possible risks the future might hold whichever world actually eventuates. Contingency plans can then be developed to manage those risks.

One of the key tasks in initiating a scenario planning exercise is to identify the "Official Future": the future as it is supposed to be, and upon which prevailing strategy is based. Inevitably there is a large amount of "political" capital tied up in that view, often a result of group-think generated by dominant individuals, or ideology, which nobody is prepared to contest, or by business or political models which have stood the test of time but which may be ill-equipped for the future as it might unfold.

A great advantage of the technique, given that it is setting out to explore but not predict the future, is that, if done properly in a non-threatening manner, it allows for constructive discussion on alternatives taking into account the full range of credible evidence. In particular, there must be a preparedness to "think the unthinkable", beyond conventional wisdom. Once those perspectives are available and understood by the key players, a re-assessment of the Official Future is often inevitable and undertaken proactively.

And so it is with climate change policy. In Australia, the Official Future for the last two decades, has been, and remains, climate denial and delay.

Views have become incredibly polarized, based primarily on the dominance of short-term thinking in business, political expediency and blinkered ideology. The science is ignored and key advice sidelined. Policy, such as it is in Australia, reflects a desire to stay within our comfort zone, using predatory delay to prolong the life of our high-carbon economy as long as possible for short-term financial gain, irrespective of the damage it may do to the community. So wholly inadequate emission reductions, of 26-28% by 2030, are seen to be a "challenging" task. "Unthinkable" futures, for example that those targets might have to be much stronger because the world may heat to 1.5C by 2030, as the latest science suggests, are not entertained. Too much credence is given to the denialist view that climate change is a non-problem, and if anything is done at all, it should be to wait and adapt.

The global Official Future is changing rapidly as climate impacts and associated costs escalate. Leaders and institutions such as the International Energy Agency, the World Economic Forum, the World Bank, the International Monetary Fund, Academies of Science and the United Nations — along with governments in the UK, Ireland, Canada, France and Catalonia, and cities such as New York, London and Sydney, under pressure from their communities — are calling for emergency action if catastrophic climate outcomes are to be avoided. The implication is that radically different steps must be taken if the world is to seriously address the issue.

Australia's national government needs to undertake serious scenario planning, and develop contingencies for the inevitability that our Official Future of continued high-carbon, export-led growth will fall apart, probably sooner rather than later.

We have innumerable attractive options if only we can move away from the current denialist group-think. The simple scenario presented here is an initial contribution to aid that thinking.

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A 3°C SCENARIO EXPLORED

This section contains unamended extracts from the policy paper "Existential Climate-related Security Risk: A scenario approach" *on existential risk, and the brief scenario, together with annotated footnotes to explore some aspects in more detail. The policy papler is available at: breakthroughonline.org.au/papers.*

EXISTENTIAL RISK

An existential risk to civilisation is one posing permanent large negative consequences to humanity which may never be undone, either annihilating intelligent life or permanently and drastically curtailing its potential.[7]

Accounting for the commitments by nations to the 2015 *Paris Agreement*, the current path of warming is more than 3°C by 2100.[8] But this figure does not include "long-term" carbon-cycle feedbacks, which are materially relevant now and in the near future due to the unprecedented rate at which human activity is perturbing the climate system.[9] Taking these into

[7] This definition is from Prof. Nick Bostrom. It should be noted that it is not just about the risk of extinction of a species but also about *permanently and drastically curtailing its potential*. Bostrom says "Some scenarios in which humanity survives would also be existential catastrophes if they involve a permanent and drastic destruction of humanity's future potential" (Bostrom, N, n.d., "Frequently asked questions": https://www.existential-risk.org/faq.html).

[8] Climate interactive shows current Paris commitments at June 2019 are a path of 3.3°C of warming, without some feedbacks being included (ClimateInteractive, 2019, "Climate Scoreboard", climateinteractive.org/programs/scoreboard, accessed 20 June 2019).

[9] For example, in the 2017 *Fourth National Climate Assessment,* US government agencies found that "positive feedbacks (self-reinforcing cycles) within the climate system have the potential to accelerate human-induced climate change and even shift the Earth's climate system, in part or in whole, into new states that are very different from those experienced in the recent past", and whilst some feedbacks and potential state shifts can be modelled and quantified, "others can be modeled or identified but not quantified and some are probably still unknown". Hence: "While climate models incorporate important climate processes that can be well quantified, they do not include all of the processes that can contribute to feedbacks, compound extreme events, and abrupt and/or irreversible changes. For this reason, future changes outside the range projected by climate

account, the Paris path would lead to around 5˚C of warming by 2100.[10]

Scientists warn that warming of 4˚C is incompatible with an organised global community, is devastating to the majority of ecosystems, and has a high probability of not being stable.[11] The World Bank says it may be "beyond adaptation".[12] But an existential threat may also exist for many peoples and regions at a significantly lower level of warming. In 2017, 3˚C of warming was categorised as "catastrophic" with a warning that, on a path of unchecked emissions, low-probability, high-impact warming could be catastrophic by 2050.[13]

The Emeritus Director of the Potsdam Institute, Prof. Hans Joachim Schellnhuber, warns that "climate change is now reaching the end-game, where very soon humanity must choose between taking unprecedented action, or accepting that it has been left too late and bear the consequences."[14] He says that if we continue down the present path "there is a very big risk that we will just end our civilisation. The human species will survive somehow but we will destroy almost everything we have built up over the last two thousand years."[15]

A 2050 SCENARIO

2020–2030: Policy-makers fail to act on evidence that the current *Paris Agreement* path — in which global human-caused greenhouse emissions do not peak until 2030 — will lock in at least 3˚C of warming.[16] The case for a global, climate-emergency mobilisation of labour and resources to build a zero-emission economy and carbon drawdown in order to have a realistic chance of keeping warming well below 2˚C is politely ignored. As projected by Xu and Ramanathan, by 2030 carbon dioxide levels have reached 437 parts per million — which is unprecedented in the last 20 million years — and warming reaches 1.6˚C.[17]

2030–2050: Emissions peak in 2030, and start to fall consistent with an 80 percent reduction in fossil-fuel

models cannot be ruled out. Moreover, the systematic tendency of climate models to underestimate temperature change during warm paleoclimates suggests that climate models are more likely to underestimate than to overestimate the amount of long-term future change." (USGCRP, 2017, *Climate Science Special Report: Fourth National Climate Assessment, Volume I,* US Global Change Research Program, Washington, DC.)

[10] Reilly, J, et al,. 2015, *Energy and Climate Outlook: Perspectives from 2015*, MIT Program on the Science and Policy of Global Change, Cambridge MA,

[11] For example, Prof. Kevin Anderson says a 4˚C future is "incompatible with an organized global community, is likely to be 'beyond adaptation', is devastating to the majority of ecosystems, and has a high probability of not being stable" (Roberts, D, 2011, "The brutal logic of climate change", *Grist*, 6 December 2011).

[12] World Bank, 2012, *Turn Down the Heat: Why a 4˚C warmer world must be avoided*, World Bank, New York.

[13] Xu, Y, & Ramanathan, V, 2017, "Well below 2˚C: Mitigation strategies for avoiding dangerous to catastrophic climate changes", *Proceedings of the National Academy of Sciences,* 114, 10315-10323.

[14] Schellnhuber, H.J, 2018, "Foreword", in Spratt, D, and Dunlop, I, 2018, *What Lies Beneath: The understatement of existential climate risk*, Breakthrough National Centre for Climate Restoration, Melbourne..

[15] Breeze, N, 2018, op. cit.

[16] The last time atmospheric carbon dioxide (CO_2) emissions were at the current level, of around 400 ppm CO_2, was during the early-to-mid Pliocene 3–4 million years ago, when temperatures were around 3–4˚C warmer than pre-industrial (Pagani, M, et al., 2010, "High Earth-system climate sensitivity determined from Pliocene carbon dioxide concentrations", *Nature Geoscience*, 3, 27-29). Burke et al. say under the present high-emissions trajectory (RCP8.5) that "by 2030 CE, future climates most closely resemble Mid-Pliocene climates", and even under RCP4.5, "climate stabilizes at Pliocene-like conditions by 2040 CE". Pliocene-like conditions that prevailed 3–3.3 million years ago are described as temperatures being ~3˚C warmer than pre-industrial and sea levels 25 metres higher (Burke, KD., et al., 2018, "Pliocene and Eocene provide best analogs for near-future climates", *Proceedings of the National Academy of Sciences*, 115, 13288-13293).

[17] Xu, Y, & Ramanathan, V, 2017, op. cit. A number of other papers suggest the global average warming trend will reach 1.5˚C by around 2030, including: Henley, B.J, and King, A.D, 2017, "Trajectories toward the 1.5˚C Paris target: Modulation by the Interdecadal Pacific Oscillation", *Geophysical Research Letters*, 44, 4256-62; and Jacob, D, et al., 2018, "Climate impacts in europe under +1.5˚C global warming", *Earth's Future*, 6, 264-285. There is also the issue of the underestimation of current warming: the effect of calculating (1) warming for total global coverage rather than for the coverage for which observations are available, (2) warming using SATs over the entire globe instead of the observational blend of SSTs and SATs, and (3) warming from a pre-industrial, instead of a late-nineteenth century baseline, which together add approximately 0 3˚C to the estimate in IPCC (Schurer, A.P, et al., 2018, "Interpretations of the Paris climate target", *Nature Geoscience*, 11, 220-221).

energy intensity by 2100 compared to 2010 energy intensity. This leads to warming of 2.4˚C by 2050, consistent with the Xu and Ramanathan "baseline-fast" scenario.[18] However, another 0.6˚C of warming occurs — taking the total to 3˚C by 2050 — due to the activation of a number of carbon-cycle feedbacks and higher levels of ice albedo and cloud feedbacks than current models assume.[19]

It should be noted that this is far from an extreme scenario: the low-probability, high-impact warming (five percent probability) can exceed 3.5–4˚C by 2050 in the Xu and Ramanathan scheme.[20]

2050: By 2050, there is broad scientific acceptance that system tipping-points for the West Antarctic Ice Sheet[21] and a sea-ice-free Arctic summer[22] were passed well before 1.5˚C of warming, for the Greenland Ice Sheet[23] well before 2˚C, and for widespread permafrost loss[24] and large-scale Amazon drought and dieback[25] by 2.5˚C. The "Hothouse Earth" scenario has been realised, and Earth is headed for another degree or more of warming, especially since human greenhouse emissions are still significant.[26]

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[18] Xu, Y., & Ramanathan, V., 2017, op. cit.

[19] Xu and Ramanthan (2017) say that taking into account the biogeochemical feedbacks (such as less efficient land/ocean sinks, permafrost loss) effectively increases the baseline-fast carbon emissions by ~20% and can enhance warming by up to 0.5˚C. As well, models may underestimate positive ice albedo feedback from the retreat of Arctic sea ice, positive cloud albedo feedback from retreating storm track clouds in mid-latitudes, and positive albedo feedback by the mixed-phase clouds. Another issue is the higher warming for the current trajectory of greenhouse gas levels that may be implied by work-in-progress on the next generation of climate models, which are so far exhibiting a higher climate sensitivity than is currently assumed (Voosen, P, 2019, "New climate models predict a warming surge", *ScienceMag,* 16 April 2019).

[20] Xu, Y, Ramanathan, V, 2017, op. cit.

[21] Rignot, E, et al., 2014, "Widespread, rapid grounding line retreat of Pine Island, Thwaites, Smith, and Kohler glaciers, West Antarctica, from 1992 to 2011", *Geophysical Research Letters*, 41, 3502–3509. NASA's Jet Propulsion Laboratory reported in May 2014 that: "A new study by researchers… finds a rapidly melting section of the West Antarctic Ice Sheet appears to be in an irreversible state of decline, with nothing to stop the glaciers in this area from melting into the sea. The study presents multiple lines of evidence, incorporating 40 years of observations that indicate the glaciers in the Amundsen Sea sector of West Antarctica 'have passed the point of no return', according to glaciologist and lead author Eric Rignot of UC Irvine and NASA's Jet Propulsion Laboratory in Pasadena, California." (NASA JPL, 2014, "West Antarctic glacier loss appears unstoppable", 12 May 2014, www.jpl.nasa.gov/news/news.php?release=2014-148.)

[22] "The chance that there will be any permanent sea ice left in the Arctic after 2022 is essentially zero… Can we lose 75-80 percent of permanent ice and recover? The answer is no," James Anderson, Harvard University professor of atmospheric chemistry, told *Forbes* on 15 January 2018 (McMahon, J, 2015, "We have five years to save ourselves from climate change, Harvard scientist says", *Forbes*, 15 January 2018). Amongst many other expert elicitations, see Tim Lenton's assessment from 2012 (Pearce, F, 2012, "Arctic sea ice may have passed crucial tipping point", *New Scientist*, 27 March 2012).

[23] Researchers estimate the tipping point for Greenland Ice Sheet as 1.6˚C, with an uncertainty range of 0.8 to 3.2˚C (Robinson, A, et al., 2012, "Multistability and critical thresholds of the Greenland ice sheet", *Nature Climate Change,* 2, 429–432); see also Bevis, M, et al., 2019, "Accelerating changes in ice mass within Greenland, and the ice sheet's sensitivity to atmospheric forcing", *Proceedings of the National Academy of Sciences*, 116, 1934-1939.

[24] Simulations suggest that between 225 and 345GtC (10th to 90th percentile) are in thawed permafrost and may eventually be released to the atmosphere for stabilization target of 2˚C (Burke, E.J, et al., 2018, "CO2 loss by permafrost thawing implies additional emissions reductions to limit warming to 1.5 or 2˚C", *Environmental Research Letters*, 13, 024024). Some scientists consider that 1.5˚C appears to be something of a "tipping point" for extensive permafrost thaw (Vaks, A. et al., 2013, "Speleothems reveal 500,000-year history of Siberian permafrost", *Science,* 340, 183-186).

[25] "We believe that negative synergies between deforestation, climate change, and widespread use of fire indicate a tipping point for the Amazon system to flip to non-forest ecosystems in eastern, southern and central Amazonia at 20-25% deforestation. The severity of the droughts of 2005, 2010 and 2015-16 could well represent the first flickers of this ecological tipping point. These events, together with the severe floods of 2009, 2012 (and 2014 over SW Amazonia), suggest that *the whole system is oscillating*" (Lovejoy, T.L, and Nobre, C, 2018, "Amazon Tipping Point", *Science Advances*, 4, eaat2340) (emphasis added). The drying of the Amazon basin may become so severe than in some models rainfall decreases to zero and the area becomes essentially desert (for more, see Lynas, M, 2007, *Six Degrees*, Fourth Estate, London, p. 130).

[26] The "Hothouse Earth" scenario is one in which system feedbacks and their mutual interaction could drive the Earth System climate to a 'point of no return',

While sea levels have risen 0.5 metres by 2050, the increase may be 2–3 metres by 2100,[27] and it is understood from historical analogues that seas may eventually rise by more than 25 metres.[28]

Thirty-five percent of the global land area, and 55 percent of the global population, are subject to more than 20 days a year of lethal heat conditions, beyond the threshold of human survivability.[29]

The destabilisation of the Jet Stream[30] has very significantly affected the intensity and geographical distribution of the Asian and West African monsoons[31] and, together with the further slowing of the Gulf Stream[32], is impinging on life support systems in Europe[33]. North America suffers from devastating

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whereby further warming would become self-sustaining (without further human perturbations). This threshold could exist at a temperature rise as low as 2˚C (Steffen, W, et al., 2018, "Trajectories of the Earth System in the Anthropocene", *Proceedings of the National Academy of Sciences*, 115, 8252-8259). Steffen told *The Guardian*: "I think the dominant linear, deterministic framework for assessing climate change is flawed, especially at higher levels of temperature rise. So, yes, model projections using models that don't include these processes indeed become less useful at higher temperature levels. Or, as my co-author John Schellnhuber says, we are making a big mistake when we think we can 'park' the Earth System at any given temperature rise – say 2˚C – and expect it to stay there" (Readfearn, G, 2018, "Earth's climate monsters could be unleashed as temperatures rise", *The Guardian*, 6 October 2018).

[27] "Our findings support the use of scenarios of 21st century global total sea-level rise exceeding 2 metre for planning purposes" (Bamber, J.L, et al., 2019, "Ice sheet contributions to future sea-level rise from structured expert judgment", *Proceedings of the National Academy of Sciences*, 116, 11195-11200).

[28] Rohling, E.J, et al., 2009, "Antarctic temperature and global sea level closely coupled over the past five glacial cycles", *Nature Geoscience,* 2, 500–504.

[29] The phrase "beyond the threshold of human survivability" could more aptly say "beyond survivability for the most vulnerable and exposed". The 35% and 55% figures are based on Mora, C, et al. (2017. "Global risk of deadly heat", *Nature Climate Change*, 7, 501-506) who find that at 2˚C approx. 26% of land area and 48% of global population are subject to "deadly heat"; at 4˚C the figures are 47% and 74%. The authors define "deadly" as "climatic conditions that are projected to cause death", based on analysis of climate conditions during past, documented cases of excess mortality. That is, heat stress conditions which have caused mortality amongst the more vulnerable or exposed members of the population. This is a lower level of threat than exceedance of the 35˚C Wet Bulb Temperature mark, discussed in footnote 45 below. According to Xu and Ramanathan (2017) deadly heat is defined as "exceeding a threshold of temperature as well as humidity" which "*could* pose existential risks to humans and mammals alike unless adaptation measures are implemented, such as providing air conditioning to the entire population or a massive relocation of most of the population to safer climates". There is "the likelihood of approximately half of the population exposed to deadly heat by 2050" (Ramanathan, V, et al., 2018, "Climate extremes and global health', *Foreign Affairs*, 31 July 2018).

[30] Climate change and the severe loss of summertime Arctic sea ice enhance Northern Hemisphere jet stream meandering, intensifying Arctic air mass invasions toward middle latitudes such as the cold air outbreaks in Central Europe and North America in winter, and increasing the frequency of atmospheric blocking events like the one that steered Hurricane Sandy west into the densely populated New York City area. In the summer, a weakened Jet Stream leads to prolonged heat waves and dry conditions, like those experienced in Europe, for example in 2003, 2006, 2015 and 2018 (Alfred Wegener Institute, 2019, "A warming Arctic produces weather extremes in our latitudes", *PhysOrg*, 29 May 2019), and in 2019.

[31] There has been a shift westward of the Indian summer monsoon, and rainfall has become more variable. In West Africa, the long drying trend in the Sahel is related primarily to anomalies in the months of August and September, which are considered to be the peak monsoon season. As well, "Several studies have concluded that 3 to 5˚C global warming is likely to be the threshold for tipping points such as the… collapse of the West African monsoon" (Xu, Y, & Ramanathan, V, 2017, op. cit.).

[32] The Gulf Stream, more properly the Atlantic Meridional Overturning Circulation (AMOC), which has been weakening for several centuries, has slowed 15% since the mid-20th century (Caesar, L, et al., 2018, "Observed fingerprint of a weakening Atlantic Ocean overturning circulation", *Nature* 556, 191-196), and the rate of change is accelerating, with climate models projecting further slow down. The near-term loss of summer Arctic sea ice will drive an accelerating rate of ice mass loss from Greenland, and contribute to a further slowdown of AMOC. An AMOC slowdown would reduce regional warming a little, especially in Europe, but would also lead to a reduction of ocean carbon dioxide uptake, and thus an acceleration of global-scale warming (USGCRP, 2017, op cit.).

[33] In Europe, the destabilisation of the Jet Steam will contribute to prolonged heat waves and dry conditions with blazing summers, lethal heartwaves and more intense wildfires, and droughts, impacting food production. As one example, the 2003 European heat wave led to about 70,000 premature mortalities (Robine, J.M, et al., 2008, "Death toll exceeded 70,000

weather extremes including wildfires, heatwaves, drought and inundation.[34] The summer monsoons in China have failed[35], and water flows into the great rivers of Asia are severely reduced by the loss of more than one-third of the Himalayan ice sheet[36]. Glacial loss reaches 70 percent in the Andes[37], and rainfall in Mexico and central America falls by half.[38] Semi-permanent El Nino conditions prevail.[39]

in Europe during the summer of 2003", *Comptes Rendus Biologies*, 331, 171–178). In August 2010, anomalous forest fires in Russia wiped out a quarter of the grain crop, prompting the country to ban all wheat exports, which together with a drought in China that reduced wheat yields, drove up the cost of wheat on the world market. This price spike contributed to the "Arab Spring" revolt across the Middle East and North Africa, which is the region of the world most dependent on grain imports.

[34] "More frequent and intense extreme weather and climate-related events, as well as changes in average climate conditions, are expected to continue to damage infrastructure, ecosystems, and social systems that provide essential benefits to communities. Future climate change is expected to further disrupt many areas of life, exacerbating existing challenges to prosperity posed by ageing and deteriorating infrastructure, stressed ecosystems, and economic inequality… Extreme weather and climate-related impacts on one system can result in increased risks or failures in other critical systems, including water resources, food production and distribution, energy and transportation, public health, international trade, and national security. The full extent of climate change risks to interconnected systems, many of which span regional and national boundaries, is often greater than the sum of risks to individual sectors." (USGCRP, 2017, op cit.)

[35] This part of the scenario may seem an outlier, but a 3˚C-warmer world may be characterised by semi-permanent El Nino conditions (see footnote 39 below). The El Niño–Southern Oscillation has been recognized as a major factor of the year-to-year variability of the East Asian monsoon. Anomalous dry conditions over southeastern China seem to occur during central Pacific El Niños, and crop production trends may experience a reduction and instability in some regions (Yuan, Y, and Yang, S, 2012, "Impacts of different types of El Niño on the East Asian climate: Focus on ENSO Cycles", *Journal of Climate*, 25, 7702–7722).

[36] In fact, the "one-third" figure seems too conservative. As glaciers melt the regions bounding the Indus and Ganges, rivers will experience severe flooding, but that trend is likely to shift into reverse in the second half of the century and floods will be replaced by shrinkage in water flow to around 1.9 billion people who live along those rivers (Temple, J, 2019, "India's water crisis is already here. Climate change will compound it", MIT Technology Review, 24 April 2019). The inland backflow of salt water, caused by higher sea levels, will contaminate low-lying, fertile delta regions. Declassified US spy satellite images from the mid-1970s have allowed researchers to determine that the glaciers may have lost as much as a quarter of their mass over the last four decades, the rate is accelerating, and the yearly loss since 2000 has been about 1%. If these trends continue and the rate of loss continues to rise, more than half the ice sheet will be lost by 2050, perhaps up to two-thirds (Maurer, J.M, et al., 2019, "Acceleration of ice loss across the Himalayas over the past 40 years", *Science Advances*, 5, eaav7266; ABC/AP, 2019, "Cold War spy satellite images show Himalayan glaciers are melting fast' , *ABC News,* 20 June 2019). Glaciologist Lonnie Thompson of Ohio State University told an Asia Society conference in 2009 that if melting continued at current levels, two-thirds of the plateau's glaciers would likely be gone by 2050, and that well before then, a threshold will have been hit in which people who depend on the water will start to start to see supplies dwindle (Gardner, T, 2009, "Tibetan glacial shrink to cut water supply by 2050", *Reuters*, 17 January 2009). Without these glaciers, summer monthly water inputs in an average year would be down by 38% in the upper Indus basin, and by up to 58% in drought conditions. In addition, India's national water supply is forecast to fall 50% below demand as early as 2030, and increasing irregularities in the pattern of monsoon rains are likely to undermine South Asia's agricultural and domestic water needs. By 2022, India is projected to overtake China's population, becoming the most populous country in the world with 1.4 billion. This would continue to rise to 1.5 billion by 2030, and 1.7 billion by mid-century.

[37] Tropical Andes' glaciers have already lost on average 30–50 percent of their surface area and volume since the late 1970s, and may disappear within 40 years (Pappas, S, 2013, "Andes glaciers vanishing rapidly, study finds", *LiveScience*, 23 January 2013; Eleftheriou, K, 2015, "World's highest glaciers, in Peruvian Andes, may disappear within 40 years", *ABC News*, 6 November 2015),

[38] In his book *Six Degrees*, Mark Lynas reports that in a 3˚C-warmer world: "Although precipitation in the deep tropics is projected to increase, the subtropics get drier, and Central America is right in the middle of one of these drying zones. The Hadley centre model predicts rainfall declines of 1–2 mm per day, half of the total annual rainfall in some areas." Lynas says that, like during the Mayan collapse, lower rainfall means more intense droughts, worsening deforestation, and this is why Central America is identified as one of the world's climate hotpots.

[39] During the mid-Pliocene, when CO_2 levels were similar to today, there are also strong indications that permanent El Niño conditions prevailed. Hansen says

Aridification emerges over more than 30 percent of the world's land surface.[40] Desertification is severe in southern Africa[41], the southern Mediterranean[42], west Asia, the Middle East, inland Australia and across the south-western United States.[43]

Impacts: A number of ecosystems collapse, including coral reef systems, the Amazon rainforest and in the Arctic.[44]

Some poorer nations and regions, which lack capacity to provide artificially-cooled environments for their populations, become unviable.[45] Deadly heat conditions persist for more than 100 days per year in West Africa, tropical South America, the Middle East and South-East Asia,[46] which together with land

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that rapid warming today is already heating up the western Pacific Ocean, a basis for a coming period of "super El Niños" (Hansen, J, et al, 2006, "Global temperature change", *Proceedings of the National Academy of Sciences*, 103, 14288-93).

[40] "Beyond 2050, as much as 44 percent of the planet's land areas will be exposed to drying. This will lead to severe drought conditions throughout southern Europe, North America (mainly the eastern and southwestern United States and Mexico), much of southeast Asia, and most of the Amazon—affecting about 1.4 billion people. In the latitude bands between 30 degrees N and 30 degrees S the probability of multi-decadal drought will rise to 80 percent" (Xu, Y, & Ramanathan, V, 2017, op. cit.).

[41] Thomas, D.S.G, et al., 2005, "Remobilization of southern African desert dune systems by twenty-first century global warming", *Nature* 435, 1218-21.

[42] Gibelin, A-L, and Déqué, M, 2003, "Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution mode", *Climate Dynamics*, 20, 237-339. As one example, Christos Zerefos, head of the Research Center for Atmospheric Physics and Climatology at the Academy of Athens, says, "Around 30 percent of Greece could be threatened with desertification" (Elafros, Y, 2019, "Greece faced with threat of future desertification", *Ekathimerini*, 19 June 2019).

[43] Marvel, K, 2019, "Creeping toward permanent drought", *Scientific American*, 12 June 2019.

[44] See footnotes 22 and 25 above. Coral systems will be reduced to <10% at 1.5˚Cof warming (Frieler, K, et al., 2013, "Limiting global warming to 2˚C is unlikely to save most coral reefs", *Nature Climate Change,* 3, 165-170). By 2˚C, Australia's Great Barrier Reef could expect a significant bleaching event almost every year (King, A.D, et al., 2017, "Australian climate extremes at 1.5˚C and 2˚C of global warming", *Nature Climate Change,* 7, 412-416)

[45] Another and more stringent understanding of "lethal heat", different from Mora et al. described above, is one in which conditions are beyond the physiologic threshold for survival of healthy humans outdoors, which occurs when the Wet Bulb Temperature (WBT), a measure of both temperature and humidity, exceeds 35˚C for more than six hours, Under the IPCC high-emissions or business-as-usual (BAU) RCP8.5 scenario, warming by 2100 is in the range of 3–4˚C (technically, median of 3.7˚C and very likely between 2.6-4.8˚C), so high-emissions projections of deadly heat are relevant to our scenario. The fertile North China Plain is the heartland of modern China and has experienced a vast expansion of irrigated agriculture but, under a BAU scenario, the "North China Plain is likely to experience deadly heatwaves with WBT exceeding the threshold defining what Chinese farmers may tolerate while working out doors" (Kang, S. and Eltahir, E.A.B, 2018, "North China Plain threatened by deadly heatwaves due to climate change and irrigation", *Nature Communications*, 9, 2894). Another study found that under the BAU scenario, extremes of WBT in South Asia are likely to approach and, in a few locations, exceed the critical threshold, with the most extreme hazard from future heat waves concentrated around densely populated agricultural regions of the Ganges and Indus river basins. The authors say that "Climate change, without mitigation, presents a serious and unique risk in South Asia, a region inhabited by about one-fifth of the global human population, due to an unprecedented combination of severe natural hazard and acute vulnerability." (In, E.S, et al., 2017, "Deadly heat waves projected in the densely populated agricultural regions of South Asia", *Science Advances*, 3, e1603322). A third study found that extremes of WBT in the region around the Arabian Gulf are likely to approach and exceed the critical threshold under a BAU emissions scenario, particularly Abu Dhabi, Dubai, Doha and coastal cities in Iran. (Pal, J.S, and Eltahir, E.A.B, 2016, "Future temperature in southwest Asia projected to exceed a threshold for human adaptability", *Nature Climate Change,* 6, 128–129.). Jos Lelieveld, Director at the Max Planck Institute for Chemistry, says that If emissions continue to grow at the current rate, average temperatures in summer will rise by about 5 degrees Celsius in the Middle East and North Africa by mid-century (Hergersberg, P, 2016 "Hot Air in the Orient", Max Planck Research, 4-16, 62-68).The fatal 35˚C WBT level was almost reached in Bandar Mahshahr in Iran in July 2015, where 46˚C heat combined with 50% humidity, and this was at just 1˚C of global average warming.

[46] Under high-emissions scenarios, by 2100 (warming range around 3–4˚C), "mid-latitudes will be exposed to ~60 days per year [of deadly heat compared to almost the entire year in humid tropical areas" (Mora, C. et al., 2017, op cit.).

degradation and rising sea levels contributes to perhaps a billion people being displaced.[47]

Water availability decreases sharply in the most affected regions at lower latitudes (dry tropics and subtropics), affecting about two billion people worldwide.[48] Agriculture becomes nonviable in the dry subtropics.[49]

[47] How many people could be displaced internally and externally by all these processes? Nobody knows. The Syrian war, in part driven by climate factors — an epoch drought and a climate-driven spike in wheat prices/Arab Spring — led to the internal and external displacement of 11 million people in a population of 17 million. Virtually no-one saw this coming. The capacity to map physical climate changes onto social and political outcomes and people displacement on a global scale in a hotter world is poor. But here are some pointers:.

- In 2007 senior US national security analysts including, a former CIA director, concluded that: "Perhaps the most worrisome problems associated with rising temperatures and sea levels are from large-scale migrations of people — both inside nations and across existing national borders… potentially involving hundreds of millions of people. The more severe scenarios suggest the prospect *of perhaps billions of people over the medium or longer term* being forced to relocate. The possibility of such a significant portion of humanity on the move, forced to relocate, poses an enormous challenge even if played out over the course of decades." (emphasis added) (Campbell, K.M, et al., 2007, op cit.)
- The UN says that: "Unless we change the way we manage our land, in the next 30 years we may leave *a billion or more vulnerable poor people with little choice but to fight or flee*" (emphasis added) (UN Convention to Combat Desertification, n.d., "Sustainability. Stability. Security." www.unccd.int/sustainability-stability-security).
- As noted above, Xu and Ramanathan (2017) conclude "the likelihood of approximately half of the population exposed to deadly heat by 2050", "which could pose existential risks to humans and mammals alike unless adaptation measures are implemented, such as providing air conditioning to the entire population *or a massive relocation of most (sic!) of the population to safer climates*" (emphasis added) .
- The 2018 *Global Catastrophic Risks* report says that even for 2˚C of warming more than a billion people may need to be relocated (Wariaro, V, et al., 2018, *Global Catastrophic Risks 2018*, Global Challenges Foundation, Stockholm).
- The annual Global Peace Index estimated 971 million people live in areas with high or very high exposure to climate hazards including cyclones, floods, bushfires, desertification and rising sea levels. According to the Internal Displacement Monitoring Centre, more than 265 million people have been internally displaced by natural disasters since 2008 (Shelton, T, 2019, "Nearly a billion people facing high exposure to climate change effects, Global Peace Index finds", *ABC News*, 12 June 2019).

[48] Approximately 1.8 billion people around the world lack access to safe drinking water and nearly two billion people lack access to sanitation. According to the 2017 report, *Global Trends: Paradox of Progress* (US National Intelligence Council, Washington DC) "more than 30 countries — nearly half of them in the Middle East — will experience extremely high water stress by 2035, increasing economic, social, and political tensions". The CNA Military Advisory Board's 2014 report, *National Security Risks and the Accelerating Risks of Climate Change*, says that: "From today's baseline of 7.1 billion people, the world's population is expected to grow to more than 8 billion by 2025… by 2030, population growth and a burgeoning global middle class will result in a worldwide demand for 35% more food and 50% more energy. Rising temperatures across the middle-latitudes of the world will increase the demand for water and energy. These growing demands will stress resources, constrain development, and increase competition among agriculture, energy production, and human sustenance. In light of projected climate change, stresses on the water-food-energy nexus are a mounting security concern across a growing segment of the world." India's national water supply is forecast to fall 50% below demand as early as 2030, and increasing irregularities in the pattern of monsoon rains are likely to undermine South Asia's agricultural and domestic water needs (Ahmed, N.M, 2017, *Failing States, Collapsing Systems: Biophysical triggers of political violence*, Springer Briefs in Energy, Cham Switzerland). China contains 20% of global population but only 7% of available fresh water. 54% of the main rivers contain water unfit for human consumption (Cho, R, 2011, "How China is dealing with its water crisis", State of the Planet, *Columbia University Earth Institute News*, http://blogs.ei.columbia.edu/2011/05/05/how-china-is-dealing-with-its-water-crisis). A World Bank report on China's water situation foresees "catastrophic consequences for future generations" unless water use and supply can quickly be brought back into balance (Brown, L, 2013, "The real threat to our future is peak water", *The Guardian*, 6 July 2013).

[49] "Agriculture becomes nonviable in the dry subtropics, where irrigation becomes exceptionally difficult because of low water availability and increased soil salinization resulting from more rapid evaporation of water from irrigated fields. Arid regions at low latitudes expand, taking previously marginally

Most regions in the world see a significant drop in food production and increasing numbers of extreme weather events, including heat waves, floods and storms. Food production is inadequate to feed the global population and food prices skyrocket, as a consequence of a one-fifth decline in crop yields, a decline in the nutrition content of food crops, a catastrophic decline in insect populations, desertification, monsoon failure and chronic water shortages, and conditions too hot for human habitation in significant food-growing regions.[50]

The lower reaches of the agriculturally-important river deltas such as the Mekong, Ganges and Nile are inundated, and significant sectors of some of the world's most populous cities — including Chennai, Mumbai, Jakarta, Guangzhou, Tianjin, Hong Kong, Ho Chi Minh City, Shanghai, Lagos, Bangkok and Manila — are abandoned.[51] Some small islands become uninhabitable.[52] Ten percent of Bangladesh is inundated, displacing 15 million people.[53]

According to the Global Challenges Foundation's *Global Catastrophic Risks 2018* report, even for 2°C of warming, more than a billion people may need to be relocated due to sea-level rise, and In high-end scenarios "the scale of destruction is beyond our capacity to model, with a high likelihood of human civilisation coming to an end".[54]

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productive croplands out of production" (Campbell, KM, et al., 2007, op cit.).

[50] "Heat and droughts threaten regions that produce much of the world's food. Food prices are expected to raise 23 percent by 2030, making food markets more volatile, and under heat stress the nutritious content of food crops is declining" (Ramanathan, V, et al., 2018 "Climate extremes and global health' , *Foreign Affairs*, 31 July 2018), "In the tropics and sub-tropics, geographic areas that include the world's hungriest people, climate change could cause crop yields to fall 10 to 20 percent or more between now and 2050" (Thornton, P, 2012, *Recalibrating food production in the developing world: global warming will change more than just the climate*, CCAFS Policy Brief 6, CGIAR Research Program on Climate Change, Agriculture and Food Security). "Under current production systems and practices, our models indicate aggregate crop yields [in the USA] could decrease during the end of the century (2050–2100) by 8%–19% under the mildest scenario (RCP 2.6), and by 20%–48% under the most severe scenario (RCP 8.5)." (Ortiz-Bobea, A, et al., 2019, "Unpacking the climatic drivers of US agricultural yields", *Environmental Research Lett*ers, 14, 064003) "Climate models project increased aridity in the 21st century over most of Africa, southern Europe and the Middle East, most of the Americas, Australia, and Southeast Asia" (Dai, A., 2010, "Drought under global warming: a review", *WIREs Climate Change*, 2, 45-65).

[51] "Chennai" should be "Kolkata". For "Manila" read "Miami". A 2011 study (Hanson, S, et al., 2011, "A global ranking of port cities with high exposure to climate extremes", *Climatic Change,* 104, 89–111) assessed the impacts of climate change on coastal cities on a 2070s timescale, with a global rise of 0.5 metre in sea level above current levels. The analysis considers a number of factors which could affect current and future exposure, including population and economic growth, natural subsidence/uplift, global sea-level rise and potential human-induced subsidence. Sea levels have already risen ~0.2 metre, so this is effectively a 0.7 metre study from a late 19th century baseline. The top 20 cities ranked in terms of population exposed to coastal flooding in the 2070s were:
Kolkata (Calcutta) 14,014,000
Mumbai (Bombay) 11,418,000
Dhaka 11,135,000
Guangzhou 10,333,000
Ho Chi Minh City 9,216,000
Shanghai 5,451,000
Bangkok 5,138,000
Rangoon 4,965,000
Miami 4,795,000
Hai Phòng 4,711,000
Alexandria 4,375,000
Tianjin 3,790,000
Khulna 3,641,000
Ningbo 3,305,000
Lagos 3,229,000
Abidjan 3,110,000
New York-Newark 2,931,000
Chittagong 2,866,000
Tokyo 2,521,000
Jakarta 2,248,000
See also: Holder, J, et al., (2017), "The three-degree world: the cities that will be drowned by global warming", *The Guardian*, 3 November 2017.

[52] Storlazzi, C.D, et al., 2018, "Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding", *Science Advances*, 4, eaap9741.

[53] A one-metre sea level rise would flood 20% of the area of Bangladesh and displace 30 million people, according to Maj. Gen. Munir Muniruzzaman, former military adviser to the president of Bangladesh and chairman of the Global Military Advisory Council on Climate Change (Daily Mail, 2016, "Military experts warn of "epic' humanitarian crisis sparked by climate change", *Daily Mail*, 1 December 2016).

[54] Wariaro, V, et al., 2018, op cit.

National security consequences: For pragmatic reasons associated with providing only a sketch of this scenario, we take the conclusion of the *Age of Consequences* "Severe' 3˚C scenario[55] developed by a group of senior US national-security figures in 2007 as appropriate for our scenario too:

> "Massive nonlinear events in the global environment give rise to *massive nonlinear societal events*. In this scenario, nations around the world will be *overwhelmed by the scale of change* and pernicious challenges, such as pandemic disease. The internal cohesion of nations will be under great stress, including in the United States, both as a result of a dramatic rise in migration and changes in agricultural patterns and water availability. The flooding of coastal communities around the world, especially in the Netherlands, the United States, South Asia, and China, has the potential to *challenge regional and even national identities*. Armed conflict between nations over resources, such as the Nile and its tributaries, is likely and nuclear war is possible. The social consequences range from increased religious fervor to *outright chaos*. In this scenario, climate change provokes *a permanent shift in the relationship of humankind to nature*' (emphasis added)."

[55] Campbell, K.M, et al. 2007, op cit.

THE AGE OF CONSEQUENCES FULL 3ºC SCENARIO

BACKGROUND

*In 2007 the Centre for Strategic and International Studies and the Centre for New American Security published "*The Age of Consequences: The foreign policy and national security implications of global climate change"*. Its eleven authors included R. James Woolsey, a former director of the CIA, John Podesta, former chief of staff to Bill Clinton, and a range of physical and social scientists and national security analysts. At the heart of the study were three plausible scenarios of future climate change, and their national security consequences. The middle of the three scenarios was entitled "Severe climate change over the next 30 years", and laid out a scenario in which warming had reached 2.6˚C above 1990 levels (just over 3˚C compared to the late 19th century) and a 0.52 metre sea level rise. Here we reproduce that scenario from the report. It is a chilling assessment and adds to the picture of what the world could look like at 3˚C of warming.*

SCENARIO: CLIMATE CHANGE OVER THE NEXT 30 YEARS

At a glance:

Time span: 30 Years
Warming 2.6˚C (over 1990 levels)
Sea Level rise: 0.52 metres

SCENARIO OVERVIEW: SEVERE CLIMATE CHANGE

The projection of severe climate change employed in this chapter is based on IPCC findings, with an adjustment to account for possible "tipping point" events such as the abrupt release of massive quantities of methane from melting tundra or of carbon dioxide as the sea warms up. Under these conditions, adverse trends could accelerate abruptly:

- Over the next 30 years, average global surface temperature rises unexpectedly to 2.6˚C above 1990 levels, with larger warming over land and sheets accelerate rapidly, resulting in 52 centimeters of sea level rise. Based on these observations and improved understanding of ice sheet dynamics, climate scientists by this time express high confidence that the Greenland and West Antarctic Ice Sheets have been destabilized and that 4 to 6 meters of sea level rise are now

inevitable over the next few centuries, bringing intense international focus to this problem.

- Water availability decreases strongly in the most affected regions at lower latitudes (dry tropics and subtropics), affecting 1 to 2 billion people worldwide. The North Atlantic overturning circulation slows significantly, with consequences for marine ecosystem productivity and fisheries.
- Crop yields decline significantly in the fertile river deltas because of sea level rise and damage from increased storm surges. Agriculture becomes essentially nonviable in the dry subtropics, where irrigation becomes exceptionally difficult because of dwindling water supplies, and soil salinization is exacerbated by more rapid evaporation of water from irrigated fields. Arid regions in the low latitudes have spread significantly by desertification, taking previously marginally productive crop lands out of production.
- Global fisheries are affected by widespread coral bleaching, ocean acidification, substantial loss of coastal nursery wetlands, and warming and drying of tributaries that serve as breeding grounds for anadromous fish.
- The Arctic Ocean is now navigable for much of the year because of decreased Arctic sea ice and the Arctic marine ecosystem is dramatically altered. Developing nations at lower latitudes are impacted most severely because of climate sensitivity and high vulnerability. Industrialized nations to the north experience net harm from warming and must expend greater proportions of GDP adapting to climate change at home.

This projection serves as the basis for a scenario depicting the possible societal consequences of severe climate change over the course of thirty years. These consequences are not to be taken as predictions: they represent a selected construct of the future, intended to encourage reflection about the consequences of continued inaction.

The Role of Complexity

Climate change is a manifestation of phenomena that are complex in the technical sense of that word. Complex phenomena are nonlinear and unstable, "Nonlinear" means that incremental change in the level of inputs to a system can result in major, and even discontinuous changes in the system's output, "Unstable" means that it is not possible to create a single, normative model for the system's behavior: instead, modeling must assume the possibility of surprise. It is readily seen that even incremental levels of climate change will have political consequences, but a less obvious, and major, premise of this chapter is that *nonlinear climate change will produce nonlinear political events*.

If the environment deteriorates beyond some critical point, natural systems that are adapted to it will break down. This applies also to social organization. Beyond a certain level climate change becomes a profound challenge to the foundations of the global industrial civilization that is the markof our species.

REGIONAL SENSITIVITY TO SEVERE CLIMATE CHANGE

According to the IPCC findings the poorest nations will suffer first and also most deeply from climate change. Despite this, my analysis of the international consequences of climate change begins with the wealthiest and strongest societies since it is their responses that will make the difference between relative order and freefall.

United States

Even at lesser degrees of climate change we should expect more severe weather along our coasts, with increasingly violent storms coming in from the sea at much higher rates of incidence. Very early on in this process important social readjustments will occur—if only because of measures that the insurance and mortgage industries will take in their own defense. This is already visible along the Gulf Coast in Hurricane Katrina's aftermath.

Even at linear rates of sea level rise, such as those forecast at the lower range of the scenario, exponentially greater numbers of people would be affected. One storm model concludes that what is now a 100-year flooding event in New York City will be a 4-year event with an additional meter of sea level.[56] Early on, there will be talk of massive engineering efforts to protect major economic centers along the coasts, including oil and gas production in the Gulf.

In our scenario, however, estimates of conditions abruptly become worse as science adjusts for new theory and new data. Given this deteriorating prospect for the future, the idea of resisting nature by brute engineering will give way to strategic withdrawal,

[56] C. Rosenzweig, C, 2004, "Using Regional Models to Assess the Potential for Extreme Climate Change," Columbia University Center for Climate Systems Research.

combined with a rear guard action to protect the most valuable of our assets. Optimists might hope for a gradual relocation of investment and settlement from increasingly vulnerable coastal areas. After a certain point, however, sudden depopulation may occur.

Severe climate change will attack the West Coast's economic foundations because of drastic, permanent water shortage — resulting not only from reduced annual rainfall, but also from the disappearance of mountain snow, whose spring melt-off is vital to the entire region's hydrology. The water requirements of the great West Coast cities are already in conflict with the region's requirements for agriculture. In the more destructive ranges of the severe scenario, it would no longer be possible to bridge this conflict through political compromise or adroit water management. Political tensions would be severe. Moreover, the damage to American agriculture will not be limited to California. There will be intensified dependence on irrigated farming in the Midwest, and this will result in the accelerated depletion of the Ogallala aquifer, upon which the entire region's agrarian economies depend.[57]

The United States' federal system may also experience stress. As noted above, one possible consequence of severe climate change will be greatly increased frequency of region-wide disasters as the result of an increasing number of especially violent storms. At some level, even a well-prepared Federal Emergency Management Agency (FEMA) system might be overwhelmed. As the cumulative magnitude of such damage increases, the federal government would likely leave state governments to shoulder more and more of the burden. The effect would be to strain the ligaments that hold the federal system together.

State governments are already pulling away from federal leadership on the environment. California is the leading example but others are coming along, mainly in the form of regional groupings.[58] The federal government is already fiscally compromised by defense costs in competition with escalating costs for maintaining the social contract. The additional costs entailed by climate change will make these problems unmanageable without drastic tradeoffs. At some point the government's ability to plan and act proactively will break down because the scale of events begins to overwhelm policies before they can generate appreciable results.

Western Hemisphere

Accumulated stresses owing to severe climate change may cause systemic economic and political collapse in Central and Latin America. The collapse of river systems in the western United States, for example, will also have a devastating effect on northern Mexico.[59] In Mexico, climate change likely means mass migration from central lowlands to higher ground. Immigration from Guatemala and Honduras into southern Mexico (whether for employment in Mexico, or passage to the United States) is already a major issue for the Mexican government, and will intensify dramatically. The pass-through consequence for the United States is that border problems will expand beyond the possibility of control, except by drastic methods and perhaps not even then. Efforts to choke off illegal immigration will have increasingly divisive repercussions on the domestic social and political structure of the United States.

Severe climate change will likely be the deathblow for democratic government throughout Latin America, as impoverishment spirals downward. In these circumstances we should expect that populist, Chavez-like governments will proliferate. Some regions will fall entirely and overtly under the control of drug cartels. Some governments will exist only nominally, and large regions will be essentially lawless, much as has been the case in Colombia. The United States will lack adequate means for responding effectively, and will likely fall back on a combination of policies that add up to quarantine.

Tensions will increase between the United States and Canada, including clashes over fishing rights on both coasts. Two-thirds of Canadians rely on the Great Lakes (a relatively small watershed).

Water levels are projected to decline by up to one foot in this century, attributable to increased evaporation, coupled with population growth. If the United States decides to divert water from the Great Lakes to compensate for the effects of climate change, the makings are in place for a fundamental clash of interests with Canada. There will also be an entirely new set of problems relating to navigation and

[57] "Ogallala Aquifer," Encyclopedia of Water Resources, at http://www.waterencyclopedia.com/Oc-Po/Ogallala-Aquifer.html.

[58] Marris, E, 2007, "Western States Reach Carbon Scheme," *Nature,* 446, 114–115.

[59] Opie, J, 1993, Ogallala: Water for a Dry Land, Lincoln: University of Nebraska Press,

resource rights, as the result of the opening of a northwest passage. It cannot be excluded that Canada's tensions with the United States will play into domestic issues affecting the stability of Canada itself: most notably, the western provinces' new role as oil exporter.

The cumulative effect of all these and related factors will be to render the United States profoundly isolated in the Western Hemisphere: blamed as a prime mover of global disaster; hated for measures it takes in self-protection.

Europe/Eurasia

The prospect of a new ice age in Europe caused by the Gulf Stream's collapse is not an element of the severe climate scenario that serves as the basis for this chapter. But there is enough bad news for Europe in the scenario as it stands. Severe climate change will threaten every major port city in Europe (the UK included). This will translate into huge economic costs at the national level, and prompt demands for EU intervention that are likely to exceed both its economic and its political resources. The Netherlands will be a particularly wrenching problem: a society at the core of European culture, which physically exists by restraining the sea, will be threatened by inundation. How will Europe share the costs of redesigning an entire nation?

Environmental pressures will accentuate the migration of peoples to levels that effectively change the ethnic signatures of major states and regions. In Europe the influx of illegal immigrants from Northern Africa and other parts of the continent will accelerate and become impossible to stop, except by means approximating blockade. There will be political tipping points marked by the collapse of liberal concepts of openness, in the face of public demands for action to stem the tide. As the pressure increases, efforts to integrate Muslim communities into the European mainstream will collapse and extreme division will become the norm.

The beginnings of these trends are present now. But severe climate change will cause them to become far worse. One of the casualties of this process may be any prospect for the cultural, much less the political integration of Turkey into the EU. Even if Turkey were to be admitted, the increasing reaction of Europeans against Islam may alienate the Turkish people, thereby destroying the hoped-for role of Turkey as a bulwark against radical Islam. At severe levels of climate change, civil disorder may lead to the suspension of normal legal procedures and rights. The precedents for dealing with large, unwanted minorities have already been set in Eurasia under fascism and communism. Under conditions marked by high levels of civil confusion and fear, political leaders and movements will emerge who might not resist these solutions.

In parts of the Russian Federation the Slavic population will continue receding while immigration from Asia intensifies. At some point these tensions may accumulate to the point where Moscow and Beijing collide over matters each believes to be vital to its own political stability and to the survival of its regime. Growing Asian settlement in portions of the Russian Federation will also result in increased friction, specifically with Russia's rapidly growing Islamic population.

The Russian core of the Federation will certainly not respond to these developments by shifting to liberal democracy. On the contrary, the antidemocratic legacy of the Putin period will be reinforced. Russia will return to its roots—to a czarist-like system in all but name, with the wealth of the country divided among a new "boyar" class as payment for loyalty. This regime will anchor itself ideologically in Russian nationalism, and economically on the basis of a dominant energy position, which it will exploit aggressively. These trends are established already. Severe climate change will intensify them under Putin's successors.

Rising sea levels and accentuated storm systems will threaten China's industrialized coastal regions. Chinese economic growth will suffer as a result of the accelerated loss of land fertility due to salinization of river deltas, compounding shortages of arable land lost to urbanization. Decreased rainfall will accelerate China's already critical shortage of water, not only for drinking but also for industrial purposes. This will also cancel out the promised effects of massive hydro-engineering projects such as the Three Gorges Dam. There will be significant environmental pressures arguing for an inland shift of economic activity. China might be better able than other societies to accomplish this kind of transition, but the western reaches of China are water and resource poor. China will also find itself in direct confrontation with Japan and even the United States over access to fish, at a time when all major fisheries will likely have crashed as the result of today's unsustainable fishing practices, combined with the ongoing, worldwide decimation of wetlands.

All this can place tremendous additional pressure on the national concept and on the Chinese political system. That system is already under stress; witness tens of thousands of clashes each year between the populace and local authorities. Political reform and liberalization of government control may be the necessary response to this kind of discontent, but severe climate change is much as well as the provincial governments, in the opposite direction.

Indian Subcontinent

On the Indian subcontinent the impact of global warming will be very destabilizing. As glaciers melt the regions bounding the Indus and Ganges Rivers will experience severe flooding. Once the ice-packs are gone the floods will be replaced by profound and protracted drought. The inland backflow of salt caused by higher sea levels, will contaminate low-lying, fertile delta regions. Bangladesh, already famously vulnerable to storm surges, will become more so as sea levels rise.

Given the subcontinent's size and the variety of its regions, it is not possible to confidently interpolate from the IPCC's very broad findings down to the specifics needed for detailed political and security analysis. It is reasonable to say, however, that new and intense environmental pressures will be bad for the internal stability of each country on the subcontinent, and bad for their relations with each other. At severe levels of climate change, the survival of Indian democracy will be at risk.

The Indus River system is the largest contiguous irrigation system on Earth with a total area of 20 million hectares and an annual irrigation capacity of more than 12 million hectares. The headwater of the basin is in India; thus India is the most powerful player.[60] Currently, Pakistan, Bangladesh, and Nepal are engaged in water disputes with India.

The Indus Water Treaty of 1960 settled some overarching issues, but frequent disagreements persist. (Pakistan now considers India in breach of the treaty for having caused "man-made river obstructions.")[61] Climate change will exacerbate these tensions. Because of India's clear upper hand, Pakistan may resort to desperate measures in seeking water security.

[60] Bajpaee, C, 2006, "Asia's Coming Water Wars," *Power and Interest News Report*, 22 August 2006.
[61] Ibid.

North Africa and the Middle East

The northern tier of African countries will face collapse as water problems become unmanageable, particularly in combination with continued population growth. Morocco may be destabilized as a result of drought-induced failure of that country's hydroelectric power system and its irrigation-based agriculture. Those countries that can afford it may follow Libya's lead and attempt to tap major aquifers in a zero-sum struggle for survival. Muammar al-Qaddafi's $20 billion mass-irrigation project would drain much of Great Nubian Sandstone Aquifer (nearly the size of Germany) in 50 years.

Newly oil-rich Sudan is seeking to irrigate some of the Sahel; Ethiopia has claimed that any Sudanese effort to divert water from the Nile would provoke military response. Egypt will clash with Sudan and/or Ethiopia over any effort by either to manipulate the flow of waters tributary to the Nile.

Efforts to design a solution to the Israeli-Palestinian struggle will be abandoned for the indefinite future because of a collective conclusion that the problem of sharing water supplies must be regarded as permanently intractable. War between Israel and Jordan over access to water is conceivable.

Moreover, Iraq, Syria, and Turkey are likely to be enmeshed in an escalating struggle over the latter's command of waters feeding the Tigris/Euphrates systems. In the Gulf countries there will be a rapid expansion of nuclear power for desalinization. This will, in turn, become a contributing factor in the regional proliferation of nuclear weapons as insurance against predation.

Rising sea levels will cause extensive damage to delta regions (normally among the most fertile and heavily settled) as sea water presses further upstream. This is already a problem in the Nile Delta, where the accelerated loss of fertile land will compound the impact of Egypt's oncoming demographic "youth bulge."

Sub-Sahara and the Horn of Africa

In sub-Saharan Africa, hundreds of millions of already vulnerable persons will be exposed to intensified threat of death by disease, malnutrition, and strife. Natural causes such as long-term drought will play a major role, but political factors will either make these disasters much worse, or even precipitate them as the result of a mix of mismanagement and miscalculated policy. Such was the case in Ethiopia during the rule of

Col. Mengistu Haile Mariam. The ongoing genocide in Darfur may have begun as a consequence of water scarcity, as noted elsewhere in this report.

Under conditions of severe global climate change environmental factors will push already failed states deeper into the abyss, while driving other states toward the brink. The stronger regional states, such as South Africa, will be affected not only by internal social and economic stress related to changing climatic patterns, but also by southward flows of refugees hoping for rescue and safety.

Contemporary Africa aspires to be a unified system but falls far short. Severe climate change would, in a grim way, provide for the first time the missing element of connectivity. From one end of the African continent to the other, severe climate change will become the common denominator of turbulence and destruction.

SYSTEMIC EVENTS

As noted above, this chapter's analytic premise is that massive nonlinear events in the global environment will give rise to massive nonlinear societal events. The specific profile of these events will vary, but very high intensity will be the norm.

- We could see class warfare as the wealthiest members of every society pull away from the rest of the population, undermining the morale and viability of democratic governance, worldwide.
- It is possible that global fish stocks will crash. Signs are that this process is already well established and accelerating. Aquaculture will expand dramatically to mitigate fish protein shortages, but the destruction of natural marine food chains will have an incalculable impact on the viability of the oceans themselves.
- Climate change may have serious impacts on disease vectors. Under conditions of extreme climate change the risk of pandemic explosions of disease increase.
- As drinkable water becomes scarcer it will become an increasingly commercialized resource. Governments, lacking the necessary resources, will privatize supply. Experience with privatized water supply in poor societies suggests the likelihood of violent protest and political upheaval.
- Human fertility may collapse in economically advanced regions, as the consequence of increasingly difficult living conditions and of general loss of hope for the longer term.
- Globalization may end and rapid economic decline may begin, owing to the collapse of financial and production systems that depend on integrated worldwide systems.
- Corporations may become increasingly powerful relative to governments as the rich look to private services. This may engender a new form of globalization in which transnational business becomes more powerful than states.
- Alliance systems and multilateral institutions may collapse—among them the UN, as the Security Council fractures beyond compromise or repair.

Moral Consequences

Massive social upheaval will be accompanied by intense religious and ideological turmoil, as people search for relief and hope. For this purpose, it is fair to consider that certain kinds of political doctrine may be thought of as religious. Fascism and communism certainly filled that role for true believers during the 20th century. Among traditional religious beliefs, the "losers" are likely to be those faiths that have formed the closest associations with the secular world and with scientific rationalism. Among political systems, authoritarian ideologies would certainly be the "winners." One way or the other, severe climate change will weaken the capacity of liberal democratic systems to maintain public confidence.

This intensified search for spiritual meaning will be all the more poignant under conditions of severe climate change. Governments with resources will be forced to engage in long, nightmarish episodes of triage: deciding what and who can be salvaged from engulfment by a disordered environment. The choices will need to be made primarily among the poorest, not just abroad but at home. We have already previewed the images, in the course of the organizational and spiritual unraveling that was Hurricane Katrina. At progressively more extreme levels, the decisions will be increasingly harsh: morally agonizing to those who must make and execute them—but in the end, morally deadening. For comparison one might look to estimates of the effects of a new global pandemic carried by avian flu.

Die-off

War and disease can be the means to achieve a grim kind of environmentally sustainable relationship between humankind and nature. Hundreds of millions of people already survive on a hand-to-mouth basis, living essentially on the leavings and limited charity of

those who are better off. As climate change deepens, even the "donor" portion of society will feel the effects, and those below will be much worse off than before.

Severe climate change will put additional stress on all systems of social support. Already tenuous health care systems may collapse. Vulnerability to new forms of disease will increase. In some regions the process may resemble the abrupt dieoffs that are thought to have occurred on a smaller scale among ancient peoples. Instead of focusing on ways to save modern civilization, social survival.

Preemptive desertion of urban civilization will occur. Attention to the long-term requirements of society will attrite, in view of a public conviction that nothing can be done to alter the downward course of events.

Survival and Reconstruction

The consequences of even relatively low-end global climate change include the loosening and disruption of societal networks. At higher ranges of the spectrum, chaos awaits. The question is whether a threat of this magnitude will dishearten humankind, or cause it to rally in a tremendous, generational struggle for survival and reconstruction.

If that rally does not occur relatively early on, then chances increase that the world will be committed irrevocably to severe and permanent global climate change at profoundly disruptive levels. An effective response to the challenge of global warming cannot be spread out across the next century, but rather must be set in place in the next decade, in order to have any chance to meaningfully alter the slope of the curves one sees in the IPCC report. We are already in the midst of choosing among alternative futures. The onset of these choices is rapid, and the consequences are likely to be irreversible.

Moreover, the upper end of the "severe, 30-year scenario" can just as well be a prelude to even worse circumstances, if the political will to deal with global warming collapses early on under the weight of universal pessimism.

In order to emerge from a period of severe climate change as a civilization with hopes for a better future and with prospects for further human development, the very model of what constitutes happiness must change. Globalization will have to be redirected. It cannot continue forever in its present form, based on an insatiable consumption of resources. The combined demands of China and India alone cannot be satisfied in a world already heavily burdened by the consumption patterns of the United States, Europe, and Japan.

Levels of demand will have to be brought into line with the availability of resources. This can occur either as the result of the collapse of the present system, or by its purposeful reconfiguration. The promise that it is possible to achieve high levels of consumption for all people everywhere would be unable to be fulfilled. The ideal of international development would be seen to have failed, with profound political consequences. Neither China nor India can voluntarily accept that their hopes for full-fledged consumer societies cannot be realized.

Conclusion

As discussed above, the reduction of humankind's burden on the environment can occur as the result of deteriorating physical conditions and attendant pandemics. It can also occur as the result of war and its aftermath. Under the circumstances described above, it is clear that even nuclear war cannot be excluded as a political consequence of global warming. Moreover, so-called "limited nuclear war" in any part of the world can escalate to a full-scale nuclear exchange among the nuclear powers. Even if one assumes that there will be very large reductions of nuclear weapons in the inventories of the United States and the Russian Federation, it should be kept in mind that the weapons on board a single submarine armed with ballistic missiles are fully capable of destroying a nation of continental size.

The alternative to reducing populations by decimation is to reduce them by demographic management. Every nation has a demographic curve, showing the rate at which the size and composition of its population will change over time, given certain assumptions. Today, advanced states use macroeconomic techniques to manage their economies: tomorrow, such states may be looking for macro-techniques to manage reproductive choice against basic targets. This is a radical departure, given the way people everywhere feel about reproductive freedom. But if the alternative is truly ruinous, what is presently unthinkable may wind up on the table. China will be an early bellwether.

Climate change represents a permanent shift in the relationship of humankind to nature. Since we already have attained the power to alter natural cycles we are now accountable for regulating our impact upon them. To fulfill this stewardship responsibly we must

improve the capacity of governance to deal with all kinds of complex phenomena: through earlier recognition and response to important challenges; deeper awareness of interactions across substantive and bureaucratic boundaries; and the ability to organize and execute policy for operation over extended periods of time.

Finding and applying the necessary political and governmental innovations is daunting, but it is a task within our capabilities, as has been repeatedly demonstrated in the course of our history.

CONCLUSION

The value of intelligent, comprehensive scenario planning can be seen in *The Age of Consequences* scenario and its willingness to "think the unthinkable". It is prescient in foreseeing circumstances that are now arising, including:

- "Border problems will expand beyond the possibility of control, except by drastic methods and perhaps not even then. Efforts to choke off illegal immigration will have *increasingly divisive repercussions on the domestic social and political structure of the United States*" (emphasis added);
- The cumulative effect of climate impacts "will be to render the United States *profoundly isolated in the Western Hemisphere*: blamed as a prime mover of global disaster; hated for measures it takes in self- protection" (emphasis added);
- "In Europe the influx of illegal immigrants from Northern Africa and other parts of the continent will accelerate and become impossible to stop, except by means approximating blockade. There will be political tipping points marked by the collapse of liberal concepts of openness, in the face of public demands for action to stem the tide. As the pressure increases, efforts to integrate Muslim communities into the European mainstream will collapse and extreme division will become the norm."

These are the tip of the iceberg, with warming now just nudging past 1˚C, compared to these scenarios which paint a feasible and much broader picture of a world 3˚C warmer.

Understanding what 3˚C of warming really means should be a great motivator for climate emergency action.

We have been warned that massive non-linear physical climate warming events will give rise to massive non-linear social events.

What will these "surprises" look like for Australia and its regions? We need to know, but we don't because this quality of scenario planning has not been done for Australia. This is the direct result of the dominant group-think of climate delay and denial which has characterised most of our political and corporate elites over the last three decades, preventing the development of sensible climate policy.

If anything, the political denial is hardening, even as the physical impacts of climate change and its economic costs mount. The fact that realistic alternative energy and other solutions are economically undercutting the traditional fossil fuels, even gas, which are enshrined in our high-carbon denialist Official Future, is testimony to the ideological myopia.

The first priority of any government is to protect its people. Climate change now represents the greatest threat to that security, far outweighing conventional geopolitical threats such as any US-China or Middle East confrontation.

Likewise, company boards have a fiduciary responsibility to ensure the viability of their organisations, and manage the threats they face, in the interests of shareholders, customers and community. Climate change is now the greatest threat to that viability, far greater than the 2008 Global Financial Crisis, as regulators around the world are now emphasising.

At present, because of the complacent group-think of our leaders, the Australian community is totally unprepared for the climate impacts which are already causing havoc across the continent, and which will escalate. This threat is not new, having been foreshadowed by the scientific community for decades.

The current Official Future is nothing less than criminal negligence by the political and corporate incumbency.

Holistic scenario planning on the real implications of climate change for Australia, encompassing the full range of possible futures, must be initiated as a matter of extreme urgency. We must rapidly rethink our Official Future before events move beyond our ability to influence outcomes. That must be done at the national level, and embraced with an all-encompassing commitment from politics, business and the community.

To gain community support for the massive economic and social changes ahead, the outcomes of such analysis must become normalised in our thinking, socialised in everyday discussion, and become the basis for planning and action.

It must be done openly, using the best expertise, without political or corporate interference sweeping inconvenient truths under the carpet, as has happened so often in the past. From now on policy must protect the future from the past, not the past from the future.

> *"Men and nations do behave wisely, once they have exhausted all other alternatives."*[62]

Having exhausted the denialist Official Future, now is the time for our new Parliament, and corporate leaders, to change direction and demonstrate they have the wisdom and leadership the Australian community deserves.

[62] Israeli foreign minister Abba Eban in 1975: https://quoteinvestigator.com/2012/11/11/exhaust-alternatives/


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WHAT LIES BENEATH

THE UNDERSTATEMENT OF EXISTENTIAL CLIMATE RISK

BY DAVID SPRATT & IAN DUNLOP | FOREWORD BY HANS JOACHIM SCHELLNHUBER

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FOREWORD

BY HANS JOACHIM SCHELLNHUBER

Hans Joachim Schellnhuber is a professor of theoretical physics specialising in complex systems and nonlinearity, founding director of the Potsdam Institute for Climate Impact Research (1992 2018) and former chair of the German Advisory Council on Global Change. He is a senior climate advisor to the European Union, the German Chancellor and Pope Francis.

What Lies Beneath is an important report. It does not deliver new facts and figures, but instead provides a new perspective on the existential risks associated with anthropogenic global warming.

It is the critical overview of well-informed intellectuals who sit outside the climate-science community which has developed over the last fifty years. All such expert communities are prone to what the French call *deformation professionelle* and the German *betriebsblindheit*.

Expressed in plain English, experts tend to establish a peer world-view which becomes ever more rigid and focussed. Yet the crucial insights regarding the issue in question may lurk at the fringes, as this report suggests. This is particularly true when the issue is the very survival of our civilisation, where conventional means of analysis may become useless.

This dilemma notwithstanding, the Intergovernmental Panel on Climate Change (IPCC) bravely perseveres with its attempts to assess the multiple cause-and-effect relationships which comprise the climate problem. After delivering five fully-fledged assessment reports, it is hardly surprising that a trend towards "erring on the side of least drama" has emerged.

There are many reasons, both subtle and mundane. Let me highlight just one of each.

Firstly, the IPCC is stricken with the *Probability Obsession*. Ever since statistics was established in the16th century, scientists have tried to capture the complex, stochastic behaviour of a given non-trivial object (such as a roulette wheel) by repeating the same experiment on that object many, many times. If there was a set of well-defined outcomes (such as the ball ending on the red or black of the wheel), then the probability of a specific outcome was simply the number of experiments delivering that outcome divided by the total number of experiments.

This sounds reasonable, but can we even imagine applying that approach to global warming? Strictly speaking, we would have to redo the Industrial Revolution and the greenhouse-gas emissions it triggered a thousand times or so, always starting with the Earth system in its 1750 pre-industrial state.

Then calculate the averaged observed outcome of that planetary experiment in terms of mean surface-temperature rise, global biological productivity, total number of climate refugees, and many other variables. This is a nonsensical notion.

Of course, climate scientists are not trying to treat the Earth like a roulette wheel, yet the statistical approach keeps on creeping into the assessments. How many times did the thermohaline circulation collapse under comparable conditions in the planetary past? How often did the Pacific enter a permanent El Niño state in the Holocene? And so on. These are valuable questions that can generate precious scientific insights.

But we must never forget that we are in a unique situation with no precise historic analogue. The level of greenhouse gases in the atmosphere is now greater, and the Earth warmer, than human beings have ever experienced. And there are almost eight billion of us now living on this planet.

So calculating probabilities makes little sense in the most critical instances, such as the methane-release dynamics in thawing permafrost areas or the potential failing of entire states in the climate crisis. Rather, we should identify *possibilities*, that is, potential developments in the planetary make-up that are consistent with the initial and boundary conditions, the processes and the drivers we know.

This is akin to scenario planning, now being proposed for assessing climate risks in the corporate sector, where the consequences of a number of future possibilities, including those which may seem highly unlikely, but have major consequences, are evaluated. This way one can overcome the probability obsession that not only fantasizes about the replicability of the singular, but also favours the familiar over the unknown and unexpected.

As an extreme example, the fact that our world has never been destroyed previously would conventionally assign probability zero to such an event. But this only holds true under steady-state assumptions, which are practically never warranted.

Secondly, there is the *Devil's Advocate Reward*. In the magnificent tradition of the Enlightenment, which shattered so many myths of the ancient regimes, scientists are trained to be sceptical about every proposition which cannot be directly verified by empirical evidence or derived from first principles (such as the invariability of the speed of light).

So, if a researcher comes up with an entirely new thought, experts tend to reflexively dismiss it as "speculative", which is effectively a death warrant in the academic world. Whereas those who criticize the idea will be applauded, rewarded and promoted! This phenomenon is evident in every seminar, colloquium or learned-society assembly.

In turn, this means that scientific progress is often driven from the periphery, or occasionally, by eminent personalities whose seniority is beyond doubt. This does not at all imply that hypotheses need not be vindicated in due course, but out-of-the-box thinking is vital given the unprecedented climate risks which now confront human civilisation.

In conclusion, one should not be overly critical of the IPCC, since the scientists involved are doing what scientists are expected to do, to the very best of their ability in difficult circumstances.

But climate change is now reaching the end-game, where very soon humanity must choose between taking unprecedented action, or accepting that it has been left too late and bear the consequences.

Therefore, it is all the more important to listen to non-mainstream voices who do understand the issues and are less hesitant to cry wolf.

Unfortunately for us, the wolf may already be in the house.

INTRODUCTION

Three decades ago, when serious debate on human-induced climate change began at the global level, a great deal of statesmanship was on display. There was a preparedness to recognise that this was an issue transcending nation states, ideologies and political parties which had to be addressed proactively in the long-term interests of humanity as a whole. This was the case even though the existential nature of the risk it posed was far less clear cut than it is today.

As global institutions, such as the United Nations Framework Convention on Climate Change (UNFCCC) which was established at the Rio Earth Summit in 1992, were developed to take up this challenge, and the extent of change this would demand of the fossil-fuel-dominated world order became clearer, the forces of resistance began to mobilise. Today, as a consequence, and despite the diplomatic triumph of the 2015 *Paris Agreement*, the debate around climate change policy has never been more dysfunctional, indeed Orwellian.

In his book *1984*, George Orwell describes a double-think totalitarian state where most of the population accepts "the most flagrant violations of reality, because they never fully grasped the enormity of what was demanded of them, and were not sufficiently interested in public events to notice what was happening. By lack of understanding they remained sane."[1]

Orwell could have been writing about climate change and policymaking. International agreements talk of limiting global warming to 1.5–2 degrees Celsius (°C), but in reality they set the world on a path of 3–5°C of warming. Goals are reaffirmed, only to be abandoned. Coal is "clean". Just 1°C of warming is already dangerous, but this cannot be admitted. The planetary future is hostage to myopic national self-interest. Action is delayed on the assumption that as yet unproven technologies will save the day, decades hence. The risks are existential, but it is "alarmist" to say so.

A one-in-two or one-in-three chance of missing a goal is normalised as reasonable. Moral hazard permeates official thinking, in that there is an incentive to ignore the risks in the interests of political expediency.

Climate policymaking for years has been cognitively dissonant, "a flagrant violation of reality". So it is unsurprising that there is a lack of understanding amongst the public and elites of the full measure of the climate challenge. Yet most Australians sense where we are heading: three-quarters of Australians see climate change as catastrophic risk,[2] and half see our way of life ending within the next 100 years.[3]

Politics and policymaking have norms: rules and practices, assumptions and boundaries, that constrain and shape them. In recent years, the previous norms of statesmanship and long-term thinking have disappeared, replaced by an obsession with short-term political and commercial advantage. Climate policymaking is no exception.

Since 1992, short-term economic interest has trumped environmental and future human needs. The world today emits 50% more carbon dioxide (CO_2) from the consumption of energy than it did 25 years ago, and the global economy has more than doubled in size. The UNFCCC strives "to enable economic development to proceed in a sustainable manner", but every year humanity's ecological footprint becomes larger and less sustainable. Humanity now requires the biophysical capacity of 1.7 Earths annually as it rapidly chews up natural capital.

A fast, emergency-scale transition to a post-fossil fuel world is absolutely necessary to address climate change. But this is excluded from consideration by policymakers because it is considered to be too disruptive. The orthodoxy is that there is time for an orderly economic transition within the current short-termist political paradigm. Discussion of what would be safe — less warming than we presently experience — is non-existent. And so we have a policy failure of epic proportions.

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3 Ra dle MJ & Eckersley R 20 5 'Publ c percep o s of fu ure hrea s o huma y a d d ffere soc e al respo ses a cross- a o al s udy *Futures* vol 72 pp 4- 6

Policymakers, in their magical thinking, imagine a mitigation path of gradual change to be constructed over many decades in a growing, prosperous world. The world not imagined is the one that now exists: of looming financial instability; of a global crisis of political legitimacy and "fake news"; of a sustainability crisis that extends far beyond climate change to include all the fundamentals of human existence and most significant planetary boundaries (soils, potable water, oceans, the atmosphere, biodiversity, and so on); and of severe global energy-sector dislocation.

In anticipation of the upheaval that climate change would impose upon the global order, the IPCC was established by the United Nations (UN) in 1988, charged with regularly assessing the global consensus on climate science as a basis for policymaking. The IPCC *Assessment Reports* (*AR*), produced every five-to-eight years, play a large part in the public framing of the climate narrative: new reports are a global media event. *AR5* was produced in 2013-14, with *AR6* due in 2022. The IPCC has done critical, indispensable work of the highest standard in pulling together a periodic consensus of what must be the most exhaustive scientific investigation in world history. It does not carry out its own research, but reviews and collates peer-reviewed material from across the spectrum of this incredibly complex area, identifying key issues and trends for policymaker consideration.

However, the IPCC process suffers from all the dangers of consensus-building in such a wide-ranging and complex arena. For example, IPCC reports, of necessity, do not always contain the latest available information. Consensus-building can lead to "least drama", lowest-common-denominator outcomes, which overlook critical issues. This is particularly the case with the "fat-tails" of probability distributions, that is, the high-impact but lower-probability events where scientific knowledge is more limited.

Vested-interest pressure is acute in all directions; climate denialists accuse the IPCC of alarmism, whereas many climate action proponents consider the IPCC to be far too conservative. To cap it all, the IPCC conclusions are subject to intense political oversight before being released, which historically has had the effect of substantially watering-down sound scientific findings.

These limitations are understandable, and arguably were not of overriding importance in the early period of the IPCC. However, as time has progressed, it is now clear that the risks posed by climate change are far greater than previously anticipated. We have moved out of the twilight period of much talk, but relatively limited climate impacts, into the harsh light of physically-evident existential threats. Climate change is now turning nasty, as we have witnessed recently in the North America, East and South Asia, the Middle East and Europe, with record-breaking heatwaves and wildfires, more intense flooding and more damaging hurricanes.

The distinction between climate science and risk is the critical issue, for the two are not the same. Scientific reticence — a reluctance to spell out the full risk implications of climate science in the absence of perfect information — has become a major problem. Whilst this is understandable, particularly when scientists are continually criticised by denialists and political apparatchiks for speaking out, it is extremely dangerous given the fat-tail risks of climate change. Waiting for perfect information, as we are continually urged to do by political and economic elites, means it will be too late to act. Time is not on our side. Sensible risk management addresses risk in time to prevent it happening, and that time is now.

Irreversible, adverse climate change on the global scale now occurring is an existential risk to human civilisation. Many of the world's top climate scientists — Kevin Anderson, James Hansen, Michael E. Mann, Michael Oppenheimer, Naomi Oreskes, Stefan Rahmstorf, Eric Rignot, Hans Joachim Schellnhuber, Kevin Trenberth and others — who are quoted in this report well understand these implications and are forthright about their findings, where we are heading, and the limitations of IPCC reports.

This report seeks to alert the wider community and business and political leaders to these limitations and urges change to the IPCC approach, to the wider UNFCCC negotiations, and to national policymaking. It is clear that existing processes will not deliver the transformation to a carbon-negative world in the limited time now available.

We urgently require a reframing of scientific research within an existential risk-management framework. This requires special precautions that go well beyond conventional risk management. Like an iceberg, there is great danger in "what lies beneath".

“We are climbing rapidly out of mankind's safe zone into new territory, and we have no idea if we can live in it."

Prof. Robert Corell, 2007


RISK
UNDERSTATEMENT

EXCESSIVE CAUTION

A 2013 study by Prof. Naomi Oreskes and fellow researchers examined a number of past predictions made by climate scientists. They found that scientists have been "conservative in their projections of the impacts of climate change" and that "at least some of the key attributes of global warming from increased atmospheric greenhouse gases have been under-predicted, particularly in IPCC assessments of the physical science". They concluded that climate 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". This may cause scientists "to underpredict or downplay future climate changes".[4]

This tallies with the view of economist Prof. Ross Garnaut, who in 2011 reflected on his experience in presenting two climate reports to the Australian Government. Garnaut questioned whether climate research had a conservative "systematic bias" due to "scholarly reticence". He pointed to a pattern across diverse intellectual fields of research predictions being "not too far away from the mainstream" expectations and observed that in the climate field that this "has been associated with understatement of the risks".[5]

As far back as 2007, then NASA climate science chief Prof. James Hansen suggested that scientific reticence hinders communication with the public about the dangers of global warming and potentially large sea-level rises. More recently he wrote that "the affliction is widespread and severe. Unless recognized, it may severely diminish our chances of averting dangerous climate change."[6]

Ten years after his 2006 climate report to the UK government, Sir Nicholas Stern reflected that "science is telling us that impacts of global warming — like ice sheet and glacier melting — are now happening much more quickly than we anticipated".[7] In 2013, he said that "Looking back, I underestimated the risks… Some of the effects are coming through more quickly than we thought then."[8]

A recent study of climate scientists found "a community which still identified strongly with an idealised picture of scientific rationality, in which the job of scientists is to get on with their research quietly and dispassionately".[9] The study said most climate scientists are resistant to participation in public/policy engagement, leaving this task to a minority who are attacked by the media and even by their own colleagues.

Kevin Trenberth, head of climate analysis at the US National Center for Atmospheric Research and a lead author of key sections of the 2001 and 2007 IPCC reports, says: "We're underestimating the fact that climate change is rearing its head… and we're underestimating the role of humans, and this means we're underestimating what it means for the future and what we should be planning for."[10]

Prof. Michael E. Mann of Pennsylvania State University says the IPCC's 2012 report on climate extremes missed an opportunity to provide politicians with a clear picture of the extent of the climate crisis: "Many scientists felt that report erred by underplaying the degree of confidence in the linkage between climate change and certain types of severe weather, including heat wave severity, heavy precipitation and drought, and hurricane intensity."[11]

4 Brysse K Oreskes N O Re lly J & Oppe he mer M 20 3 'Cl ma e cha ge pred c o Err g o he s de of leas drama? *Global Environmental Change* vol 23 o pp 327-337

5 Gar au R 20 *Update Paper 5: The science of climate change* Gar au Cl ma e Cha ge Rev ew Upda e Ca berra pp 53-55

6 Ha se J 2007 'Sc e fic re ce ce a d sea level r se *Environmental Research Letters* vol 2 o 2 024002

7 McKee R 20 6 'N cholas S er cos of global warm g " s worse ha I feared" *The Guardian* 6 November 20 6

8 S ewar H & Ell o L 20 3 'N cholas S er "I go wro g o cl ma e cha ge s far far worse" *The Guardian* 27 Ja uary 20 3

9 Hogge P & Ra dall R 20 6 'Soc ally co s ruc ed s le ce? Pro ec g pol cymakers from he u h kable Tra sforma o 6 Ju e 20 6 <h ps // www ope democracy e / ra sforma o /paul-hogge -rosemary-ra dall/soc ally-co s ruc ed-s le ce-pro ec g-pol cymakers-fr>

0 Scherer G 20 2a 'How he IPCC u deres ma ed cl ma e cha ge *Scientific American* 6 December 20 2

Scherer G 20 2b 'Cl ma e sc e ce pred c o s prove oo co serva ve *Scientific American* 6 December 20 2

Prof. Kevin Anderson of the University of Manchester says there is "an endemic bias prevalent amongst many of those building emission scenarios to underplay the scale of the 2°C challenge. In several respects, the modelling community is actually self-censoring its research (focus) to conform to the dominant political and economic paradigm…"[12]

A good example is the 1.5°C goal agreed to at the Paris December 2015 climate policy conference. IPCC assessment reports until that time (and in conformity with the dominant political paradigm) had not devoted any significant attention to 1.5°C emission-reduction scenarios or 1.5°C impacts, and the Paris delegates had to request the IPCC to do so as a matter of urgency. This is a clear case of politics driving the science research agenda. Research needs money, and too often money is allocated according to the political priorities of the day.

Anderson says it is incumbent on the scientific community to communicate research clearly and candidly to those delivering on the climate goals established by civil society, and "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."[13]

THINKING THE UNTHINKABLE

Successful risk management requires thinking "outside the box" to avoid a failure of imagination, but this is a skill rarely found at the senior levels of government and global corporations.

A 2016 report, *Thinking the unthinkable*, based on interviews with top leaders around the world, found that: "A proliferation of 'unthinkable' events… has revealed a new fragility at the highest levels of corporate and public service leaderships. Their ability to spot, identify and handle unexpected, non-normative events is… perilously inadequate at critical moments."[13]

The report findings are highly relevant to understanding the failure of climate policymaking, and the failure to adequately communicate and think about the full range of potential climate warming risks. It found that:

- The emerging picture is both scary and of great concern. Remarkably, there remains a deep reluctance, or what might be called "executive myopia" amongst top leaders in both the public and private sectors, to see and contemplate even the possibility that "unthinkables" might happen, let alone how to handle them.
- The rate and scale of change is much faster than most are even prepared to concede or respond to. At the highest board and C-suite levels, executives and their public service equivalents confess to often being overwhelmed.
- Time is at such a premium that the pressing need to think, reflect and contemplate in the ways required by the new "unthinkables" is largely marginalised.

Often blind eyes were turned, either because of a lack of will to believe the signs, or an active preference to deny and then not to engage.

While the phrase, "Thinking the unthinkable", has an attractive rhetorical symmetry, a more appropriate and accurate phrase might in many cases therefore be "Thinking the unpalatable".

These deficiencies are clearly evident at the upper levels of climate policymaking, nationally and globally. They must be corrected as a matter of extreme urgency.

2 A derso K 20 6 'Go g beyo d 'da gerous cl ma e cha ge LSE prese a o 4 February 20 6 <h p //www lse ac uk/ ewsA dMed a/ v deoA dAud o/cha els/publ cLec uresA dEve s/player aspx? d=3363>

3 A derso K 20 5 'Dual y cl ma e sc e ce *Nature Geoscience* vol 8 pp 898 900

4 Gow g N & La gdo C 20 6 *Thinking the Unthinkable: A new imperative for leadership in the digital age* Char ered I s u e of Ma ageme Accou a s Lo do

THE UNDERESTIMATION OF RISK

There are fundamental challenges in understanding and communicating risks. These include "the importance of complex interactions in shaping risks, the need for rigorous expert judgment in evaluating risks, and the centrality of values, perceptions, and goals in determining both risks and responses".[15]

IPCC reports have underplayed high-end possibilities and failed to assess risks in a balanced manner. The failure to fully account for potential future changes to permafrost (frozen carbon stores on land and under the seabed) and other carbon-cycle feedbacks is just one example.

Dr Barrie Pittock, a former leader of the Climate Impact Group in CSIRO, wrote in 2006 that "until now many scientists may have consciously or unconsciously downplayed the more extreme possibilities at the high end of the uncertainty range, in an attempt to appear moderate and 'responsible' (that is, to avoid scaring people). However, true responsibility is to provide evidence of what must be avoided: to define, quantify, and warn against possible dangerous or unacceptable outcomes."[16]

The situation has not improved. Sir Nicholas Stern said of the IPCC's *Fifth Assessment Report:* "Essentially it reported on a body of literature that had systematically and grossly underestimated the risks [and costs] of unmanaged climate change."[17]

Prof. Ross Garnaut has also pointed to the "understatement of the risks", in that we seem to be playing scientific catch-up, as reality is consistently on the most pessimistic boundary of previous projections. The Australian Climate Council reported in 2015: "Changes in the climate system are occurring more rapidly than previously projected, with larger and more damaging impacts now observed at lower temperatures than previously estimated."[18] Such a situation is not a satisfactory basis on which to plan our future.

Former senior coal fossil fuel executive and government advisor, Ian Dunlop, notes that "dangerous impacts from the underlying (warming) trend have also manifested far faster and more extensively than global leaders and negotiators are prepared to recognise".[19]

Researchers say it is important to carry out analyses "to identify what risky outcomes are possible — cannot be ruled out — starting with the biggest ones. In such analyses, it is useful to distinguish between two questions: 'What is most likely to happen?' and 'How bad could things get?'"[20]
In looking at how to reframe climate change assessments around risk, it is important to:

> " … deal adequately with low-probability, high-consequence outcomes, which can dominate calculations of total risk, and are thus worthy of special attention. Without such efforts, we court the kinds of 'failures of imagination' that can prove so costly across risk domains. Traditional climate assessments have focused primarily on areas where the science is mature and uncertainties well characterized. For example, in the IPCC lexicon, future outcomes are considered 'unlikely' if they lie outside the central 67% of the probability distribution. For many types of risk assessment, however, a 33% chance of occurrence would be very high; a 1% or 0.1% chance (or even lower probabilities) would be more typical thresholds."[21]

They emphasise that "the envelope of possibilities", that is, the full range of possibilities for which one must be prepared, is often more important than the most likely future outcome, especially when the range of outcomes includes those that are particularly severe. They conclude that the "application of scientific rather than risk-based norms in communicating climate change uncertainty has also made it easier for policymakers and other actors to downplay relevant future climate risks".[22]

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5 Mach K Mas ra drea MD B l r TE & F eld CB 20 5 'U ders a d g a d respo d g o da ger from cl ma e cha ge he role of key r sks he IPCC AR5 *Climatic Change* vol 36 pp 427-444

6 P ock AB 2006 'Are sc e s s u deres ma g cl ma e cha ge? *EOS* vol 87 o 34 pp 340-4

7 S er N 20 6 'Eco om cs Curre cl ma e models are grossly m slead g *Nature* vol 530 pp 407-409

8 S effe W Hughes L & Pearce A 20 5 *Climate Change: Growing risks, critical choices* Cl ma e Cou c l Syd ey

9 Du lop I 20 6 Foreword o Spra D 20 6 *Climate Reality Check* Break hrough Melbour e

20 Weaver C Moss R Eb K Gle ck P S er P Tebald C W lso R & Arva J 20 7 'Refram g cl ma e cha ge assessme s arou d r sk recomme da o s for he US Na o al Cl ma e Assessme *Environmental Research Letters* vol 2 o 8 08020

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A prudent risk-management approach means a tough and objective look at the real risks to which we are exposed, especially those high-end events whose consequences may be damaging beyond quantification, and which human civilization as we know it would be lucky to survive. It is important to understand the potential of, and plan for, the worst that can happen, and be pleasantly surprised if it doesn't. Focusing on middle-of-the-road outcomes, and ignoring the high-end possibilities, may result in an unexpected catastrophic event that we could, and should, have seen coming.

Prof. Robert Socolow of Princeton University says the IPCC "should communicate fully what the science community does and does not understand about high consequence outcomes.The policymaking community needs information about both probable and improbable outcomes."[23]

Integral to this approach is the issue of lower-probability, high-impact consequences known as fat-tail risks, in which the likelihood of very large impacts is actually greater than we would expect under typical statistical assumptions. A normal distribution, with the appearance of a bell curve, is symmetric in probabilities of low outcomes (left of curve) and high outcomes (right of curve) as per Figure 1(a). But, as Prof. Michael E. Mann explains, "global warming instead displays what we call a 'heavy-tailed' or 'fat-tailed' distribution, there is more area under the far right extreme of the curve than we would expect for a normal distribution, a greater likelihood of warming that is well in excess of the average amount of warming predicted by climate models,"[24] as per Figure 1(b).

In *Climate Shock: The Economic Consequences of a Hotter Planet*, economists Gernot Wagner and Martin Weitzman explore the implications of this fat-tail distribution for climate policy, and "why we face an existential threat in human-caused climate change".[25] Mann explains:

> " Let us consider… the prospects for warming well in excess of what we might term "dangerous" (typically considered to be at least 2°C warming of the planet). How likely, for example, are we to experience a catastrophic 6°C warming of the globe, if we allow greenhouse gas concentrations to reach double their pre-industrial levels (something we're on course to do by the middle of this century given business-as-usual burning of fossil fuels)? Well, the mean or average warming that is predicted by models in that scenario is about 3°C, and the standard deviation about 1.5°C. So the positive tail, defined as the +2 sigma limit, is about 6°C of warming. As shown by Wagner & Weitzman [Figure 1(b)], the likelihood of exceeding that amount of warming isn't 2% as we would expect for a bell-curve distribution. It's closer to 10%!
>
> In fact, it's actually even worse than that when we consider the associated risk. Risk is defined as the product of the likelihood and consequence of an outcome. We just saw that the likelihood of warming is described by a heavy-tailed distribution, with a higher likelihood of far-greater-than-average amounts of warming than we would expect given typical statistical assumptions. This is further compounded by the fact that the damages caused by climate change — i.e. the consequence — also increases dramatically with warming. That further increases the associated risk.
>
> With additional warming comes the increased likelihood that we exceed certain tipping points, like the melting of large parts of the Greenland and Antarctic ice sheet and the associated massive rise in sea level that would produce… Uncertainty is not our friend when it comes to the prospects for dangerous climate change."[26]

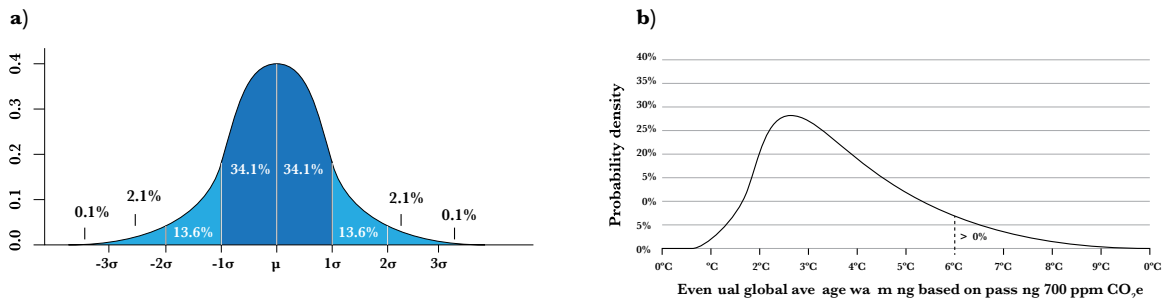

Figure 1: Normal a d "fa a l" probab l y d s r bu o s (a Normal probab l y d s r bu o a d (b a es ma e of he l kel hood of warm g due o a doubl g of gree house gas co ce ra o s exh b g a "fa a l" d s r bu o (Cred Wag er & We zma 20 5 *Climate Shock: The Economic Consequences of a Hotter Planet)*

23 Socolow R 20 'H gh-co seque ce ou comes a d er al d sagreeme s ell us more please *Climatic Change* vol 08 pp 775-790

24 Ma M 20 6 'The 'fa a l of cl ma e cha ge r sk *Huffington Post* Sep ember 20 6

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As Mann notes, risk is defined as the product of the likelihood and consequence of an outcome. This is illustrated in Figure 2, which although applied to the question of climate sensitivity (see discussion on pp. 22-23), has general applicability. The likelihood of a high-end outcome may be relatively low (right side of curve in (a)), but impacts increase at the high-end (b), showing the high risk of very unlikely events (c).

IPCC reports have not given attention to fat-tail risk analysis, in part because the reports are compiled using a consensus method, as discussed above. Prof. Stefan Rahmstorf of Potsdam University says that:

> " The magnitude of the fat-tail risks of global warming is not widely appreciated and must be discussed more. For over two decades I have argued that the risk of a collapse of the Atlantic meridional overturning circulation (AMOC) in this century is perhaps five per cent or so, but that this is far too great a risk to take, given what is at stake. Nobody would board an aircraft with a five per cent risk of crashing."[27]

He adds that: "Defeatism and doomerism is not the same as an accurate, sincere and sober discussion of worst-case risks. We don't need the former, we do need the latter." It should be noted that Rahmstorf was one of the authors of research released in April 2018 showing that, in fact, there has already been a 15% slowdown in the AMOC since the mid-twentieth century.[28]

"When all the new knowledge that challenges the old is on the more worrying side, one worries about whether the asymmetry reflects some systematic bias… I have come to wonder whether the reason why most of the new knowledge confirms the established science or changes it for the worse is scholarly reticence."

Prof. Ross Garnaut, 2011

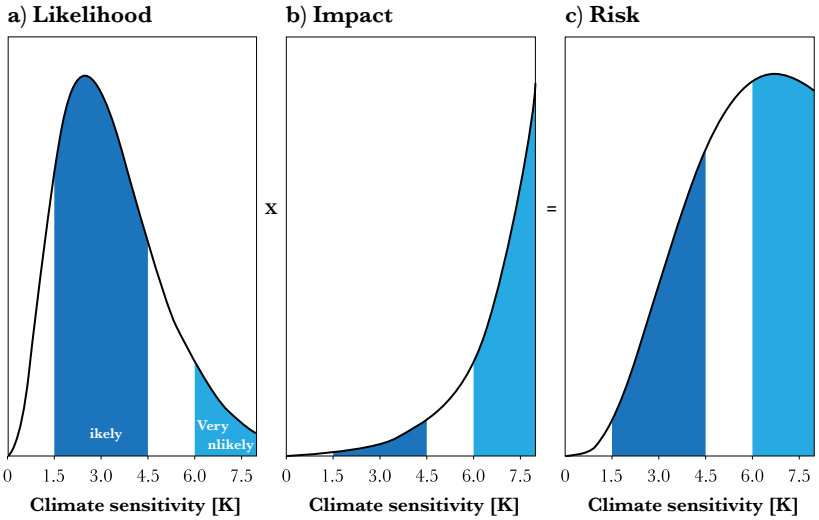

Figure 2: Schema of cl ma e-rela ed r sk (a Eve l kel hood a d (b Impac s produce (c R sk Lower l kel hood eve s a he h gh e d of he probab l y d s r bu o have he h ghes r sk (Cred RT Su o /E Hawk s

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EXISTENTIAL RISK TO HUMAN CIVILISATION

In 2016, the World Economic Forum survey of the most impactful risks for the years ahead elevated the failure of climate change mitigation and adaptation to the top of the list, ahead of weapons of mass destruction, ranking second, and water crises, ranking third. By 2018, following a year characterised by high-impact hurricanes and extreme temperatures, extreme-weather events were seen as the single most prominent risk. As the survey noted: "We have been pushing our planet to the brink and the damage is becoming increasingly clear."[29]

Climate change is an existential risk to human civilisation: that is, an adverse outcome that would either annihilate intelligent life or permanently and drastically curtail its potential.

Temperature rises that are now in prospect, after the *Paris Agreement*, are in the range of 3–5°C. At present, the *Paris Agreement* voluntary emission reduction commitments, if implemented, would result in planetary warming of 3.4°C by 2100,[30] without taking into account "long-term" carbon-cycle feedbacks. With a higher climate sensitivity figure of 4.5°C, for example, which would account for such feedbacks, the Paris path would result in around 5°C of warming, according to a MIT study.[31] A study by Schroder Investment Management published in June 2017 found — after taking into account indicators across a wide range of the political, financial, energy and regulatory sectors — the average temperature increase implied for the *Paris Agreement* across all sectors was 4.1°C.[32]

Yet 3°C of warming already constitutes an existential risk. A 2007 study by two US national security think-tanks concluded that 3°C of warming and a 0.5 metre sea-level rise would likely lead to "outright chaos" and "nuclear war is possible", emphasising how "massive non-linear events in the global environment give rise to massive nonlinear societal events".[33] The Global Challenges Foundation (GCF) explains what could happen:

> " If climate change was to reach 3°C, most of Bangladesh and Florida would drown, while major coastal cities — Shanghai, Lagos, Mumbai — would be swamped, likely creating large flows of climate refugees. Most regions in the world would see a significant drop in food production and increasing numbers of extreme weather events, whether heat waves, floods or storms. This likely scenario for a 3°C rise does not take into account the considerable risk that self-reinforcing feedback loops set in when a certain threshold is reached, leading to an ever increasing rise in temperature. Potential thresholds include the melting of the Arctic permafrost releasing methane into the atmosphere, forest dieback releasing the carbon currently stored in the Amazon and boreal forests, or the melting of polar ice caps that would no longer reflect away light and heat from the sun."[34]

29 World Eco om c Forum 20 8 *The Global Risks Report 2018: 13th Edition* World Eco om c Forum Ge eva

30 Cl ma e Ac o Tracker 20 7 'Improveme warm g ou look as I d a a d Ch a move ahead bu Par s Agreeme gap s ll looms large" 3 November 20 7 <h p //cl ma eac o racker org/publ ca o s/br efi g/288/Improveme - -warm g-ou look-as-I d a-a d-Ch a-move-ahead-bu - Par s-Agreeme -gap-s ll-looms-large h m>

3 Re lly J Pal sev S Mo er E Che H Sokolov A Hua g J Ejaz Q Sco J Morr s J & Schlosser A 20 5 *Energy and Climate Outlook: Perspectives from 2015* MIT Program o he Sc e ce a d Pol cy of Global Cha ge Cambr dge MA

32 Schroder I ves me Ma ageme 20 7 *Climate change: calibrating the thermometer* Schroders I ves me Ma ageme Lo do

33 Campbell K Gulledge J McNe ll JR Podes a J Ogde P Fuer h L Woolsley J Le o A Sm h J We z R & M x D 2007 *The Age of Consequences: The foreign policy and national security implications of global climate change* Ce re for S ra eg c a d I er a o al S ud es & Ce re for New Amer ca Secur y Wash g o

34 Global Challe ges Fou da o 20 7 *Global Catastrophic Risks 2017* Global Challe ges Fou da o S ockholm

Warming of 4°C or more could reduce the global human population by 80% or 90%,[35] and the World Bank reports "there is no certainty that adaptation to a 4°C world is possible".[36] Prof. Kevin Anderson says a 4°C future "is incompatible with an organized global community, is likely to be beyond 'adaptation', is devastating to the majority of ecosystems, and has a high probability of not being stable".[37] This is a commonly-held sentiment amongst climate scientists. A recent study by the European Commission's Joint Research Centre found that if the global temperature rose 4°C, then extreme heatwaves with "apparent temperatures" peaking at over 55°C will begin to regularly affect many densely populated parts of the world, forcing much activity in the modern industrial world to stop.[38] ("Apparent temperatures" refers to the Heat Index, which quantifies the combined effect of heat and humidity to provide people with a means of avoiding dangerous conditions.)

In 2017, one of the first research papers to focus explicitly on existential climate risks proposed that "mitigation goals be set in terms of climate risk category instead of a temperature threshold", and established a "dangerous" risk category of warming greater than 1.5°C, and a "catastrophic" category for warming of 3°C or more. The authors focussed on the impacts on the world's poorest three billion people, on health and heat stress, and the impacts of climate extremes on such people with limited adaptation resources. They found that a 2°C warming "would double the land area subject to deadly heat and expose 48% of the population (to deadly heat). A 4°C warming by 2100 would subject 47% of the land area and almost 74% of the world population to deadly heat, which could pose existential risks to humans and mammals alike unless massive adaptation measures are implemented."[39]

A 2017 survey of global catastrophic risks by the Global Challenges Foundation found that: "In high-end [climate] scenarios, the scale of destruction is beyond our capacity to model, with a high likelihood of human civilization coming to an end."[40] 84% of 8000 people in eight countries surveyed for the Foundation considered climate change a "global catastrophic risk".[41]

Existential risk may arise from a fast rate of system change, since the capacity to adapt, in both the natural and human worlds, is inversely proportional to the pace of change, amongst other factors. In 2004, researchers reported on the rate of warming as a driver of extinction.[42] Given we are now on a 3–5°C warming path this century, their findings are instructive:

- If the rate of change is 0.3°C per decade (3°C per century), 15% of ecosystems will not be able to adapt.
- If the rate should exceed 0.4°C per decade, all ecosystems will be quickly destroyed, opportunistic species will dominate, and the breakdown of biological material will lead to even greater emissions of CO_2.

At 4°C of warming "the limits for adaptation for natural systems would largely be exceeded throughout the world".[43] Ecological breakdown of this scale would ensure an existential human crisis.

By slow degrees, these existential risks are being recognised. In May 2018, an inquiry by the Australian Senate into national security and global warming recognised "climate change as a current and existential national security risk… defined as 'one that threatens the premature extinction of Earth-originating intelligent life or the permanent and drastic destruction of its potential for desirable future development'".[44] In April 2018, the Intelligence on European Pensions and Institutional Investment think-tank warned business leaders that "climate change is an existential risk whose elimination must become a corporate objective".[45] However the most recent IPCC *Assessment Report* did not consider the issue. Whilst the term "risk management" appears in the 2014 IPCC *Synthesis Report* fourteen times, the terms "existential" and "catastrophic" do not appear.

35 A derso K 20 'Go g beyo d da gerous cl ma e cha ge Explor g he vo d be wee rhe or c a d real y reduc g carbo em ss o s LSE prese a o July 20

36 World Ba k 20 2 *Turn Down the Heat: Why a 4°C warmer world must be avoided* World Ba k New York

37 Rober s D 20 "The bru al log c of cl ma e cha ge" Gr s 6 December 20 <h ps //gr s org/cl ma e-cha ge/20 - 2-05- he-bru al-log c-of-cl ma e-cha ge/>

38 Ayre J 20 7 'Ex reme hea waves w h 'appare empera ures as h gh as 55° cels us o regularly affec much of world Clea Tech ca Augus 20 7 <h ps //clea ech ca com/20 7/08/ /ex reme-hea waves-appare - empera ures-h gh-55-cels us-regularly-affec -much-world-4-cels us-warm g-pre- dus r al-levels/>

39 Xu Y & Rama a ha V 20 7 'Well below 2 °C M ga o s ra eg es for avo d g da gerous o ca as roph c cl ma e cha ges *Proceedings of the National Academy of Sciences* vol 4 pp 03 5- 0323

40 Global Challe ges Fou da o 20 7 op c

4 Goer g L 20 7 '8 0 people ow see cl ma e cha ge as a 'ca as roph c r sk survey Thomso Reu ers Fou da o 23 May 20 7 <h p // ews rus org/ em/20 70523230 48-a90de>

42 Leema s R & E ckhou B 2004 'A o her reaso for co cer reg o al a d global mpac s o ecosys ems for d ffere levels of cl ma e cha ge *Global Environmental Change* vol 4 pp 2 9 228

43 Warre R 20 'The role of erac o s a world mpleme g adap a o a d m ga o solu o s o cl ma e cha ge *Philosophical Transactions of the Royal Society A* vol 369 pp 2 7-24

44 Commo weal h of Aus ral a 20 8 *Inquiry into the Implications of climate change for Australia's national security* Fore g Affa rs Defe ce a d Trade Comm ee Depar me of he Se a e Parl ame House Ca berra

45 Murray D & Mur ha A 20 8 'Cl ma e r sk Ru g ou of me I ell ge ce o Europea Pe s o s a d I s u o al I ves me Apr l 20 8 <h ps //www pe com/repor s/spec al-repor s/ hough -leadersh p/cl ma e-r sk-ru g-ou -of- me/ 0023906 ar cle>

Existential risks require a particular approach to risk management. They are not amenable to the reactive (learn from failure) approach of conventional risk management, and we cannot necessarily rely on the institutions, moral norms, or social attitudes developed from our experience with managing other sorts of risks. Because the consequences are so severe — perhaps the end of global human civilisation as we know it — "even for an honest, truth-seeking, and well-intentioned investigator it is difficult to think and act rationally in regard to… existential risks".[46]

Existential risk management requires brutally honest articulation of the risks, opportunities and the response time frame, the development of new existential risk-management techniques outside conventional politics, and global leadership and integrated policy. Since it is not possible to recover from existential risks, "we cannot allow even one existential disaster to happen; there would be no opportunity to learn from experience",[47] but at the moment we are facing existential disasters on several climate fronts, seemingly without being able even to articulate that fact.

The failure of both the research community and the policymaking apparatus to consider, advocate and/or adopt an existential risk-management approach is itself a failure of imagination with catastrophic consequences.

PUBLIC SECTOR DUTY OF CARE ON CLIMATE RISK

Private-sector company directors internationally are facing legal action and personal liability for having refused to understand, assess and act upon climate risk, or for misrepresenting that risk. Compensation is being sought from carbon polluters for damage incurred from climate impacts. Legal opinions suggest similar action in Australia would be firmly based.

Such a duty of care extends to the public sector, including not only ministers and senior public servants, but regulators and board members of statutory authorities. As a general principle, officials in the public sector should not be held to a lower standard of account than employees of publicly listed companies. That duty has already been successfully tested in the courts in The Netherlands.

The first duty of a government is to protect the people. A government derives its legitimacy and hence its authority from the people, and so has a fiduciary duty to act in accordance with the interests of all the people with integrity, fairness and accountability.

In the climate arena, this duty has been recognised in several quarters, including by Australian Prudential Regulatory Authority Executive Director Geoff Summerhayes and Australian Securities and Investments Commissioner John Price.

This duty has a particular sharpness in the new era of disruption and existential risk that will manifest as a consequence of the global failure, and the failure of successive Australian governments, to rein in global warming.

In these circumstances, our public sector leaders have a number of specific duty-of-care responsibilities which at present are being ignored. Being a climate denier does not absolve ministers and parliamentarians of the fiduciary responsibility to set aside personal prejudice and act in the public interest.

The Australian Public Service Impartiality Value requires advice given to government to be "apolitical, frank, honest, timely and based on the best available evidence", but the overriding impression is that the federal bureaucracy, with some notable exceptions, is not treating climate change with anywhere near the seriousness and urgency it demands. Dismal reports such as the December 2017 *Review of Climate Change Policy.* are a scientifically reticent whitewash of wholly inadequate and inconsistent policies

It is entirely appropriate, when the political system fails, for affected parties to take legal action to correct such failure.

46 Bos rom N & C rkov c MM 2008 *Global Catastrophic Risks* Oxford U vers y Press Oxford
47 Op c

“We’ve reached a point where we have a crisis, an emergency, but people don’t know that. ...There’s a big gap between what’s understood about global warming by the scientific community and what is known by the public and policymakers”.

Prof. James Hansen, 2008


SCIENTIFIC
UNDERSTATEMENT

CLIMATE MODELS

Climate modelling is at the core of the work by the IPCC, and in developing future emission and warming scenarios, but it is often too conservative and underestimates future impacts.

A 2007 report on climate change and national security by the US Center for Strategic and International Studies and the Center for a New American Security recognised that: "Recent observations indicate that projections from climate models have been too conservative; the effects of climate change are unfolding faster and more dramatically than expected" and that "multiple lines of evidence" support the proposition that the 2007 IPCC reports' "projections of both warming and attendant impacts are systematically biased low". For instance:

> " The models used to project future warming either omit or do not account for uncertainty in potentially important positive feedbacks that could amplify warming (e.g., release of greenhouse gases from thawing permafrost, reduced ocean and terrestrial CO_2 removal from the atmosphere), and there is some evidence that such feedbacks may already be occurring in response to the present warming trend. Hence, climate models may underestimate the degree of warming from a given amount of greenhouse gases emitted to the atmosphere by human activities alone. Additionally, recent observations of climate system responses to warming (e.g., changes in global ice cover, sea-level rise, tropical storm activity) suggest that IPCC models underestimate the responsiveness of some aspects of the climate system to a given amount of warming."[48]

In 2015, researchers reported on the long-term feedbacks that global climate models ignore, as illustrated in Figure 3, where grey bars within the middle blue ellipse signify processes that are assumed to be partly) inactive or non-existent in global climate models, but in reality are not.[49]

In the 2017 *Fourth National Climate Assessment,* US government agencies found that "positive feedbacks (self-reinforcing cycles) within the climate system have the potential to accelerate human-induced climate change and even shift the Earth's climate system, in part or in whole, into new states that are very different from those experienced in the recent past", and whilst some feedbacks and potential state shifts can be modelled and quantified, "others can be modeled or identified but not quantified and some are probably still unknown". Hence:

> " While climate models incorporate important climate processes that can be well quantified, they do not include all of the processes that can contribute to feedbacks, compound extreme events, and abrupt and/or irreversible changes. For this reason, future changes outside the range projected by climate models cannot be ruled out. Moreover, the systematic tendency of climate models to underestimate temperature change during warm paleoclimates suggests that climate models are more likely to underestimate than to overestimate the amount of long-term future change."[50]

At the 2017 climate policy conference in Bonn, Phil Duffy, the Director of the Woods Hole Institute, explained that "the best example of reticence is permafrost… It's absolutely essential that this feedback loop not get going seriously, if it does there is simply no way to control it." He says the scientific failure occurs because "none of this is in climate models and none of this is considered in the climate policy discussion… climate models simply omit emissions from the warming permafrost, but we know that is the wrong answer because that tacitly assumes that these emissions are zero and we know that's not right".[51]

48 Campbell e al 2007 op c

49 K u R & Ruge s e MAA 20 5 'Feedbacks cl ma e se s v y a d he l m s of l ear models *Philosophical Transactions of the Royal Society A* vol 373 20 50 46

50 USGCRP 20 7 *Climate Science Special Report: Fourth National Climate Assessment* Volume I [Wuebbles DJ DW Fahey KA H bbard DJ Dokke BC S ewar & TK Maycock (eds] US Global Cha ge Research Program Wash g o DC USA

5 UPFSI 20 7 'James Ha se Sc e fic Re ce ce A Threa o Huma y a d Na ure med a co fere ce Bo 9 November 20 7 <h ps //www you ube com/wa ch?v=S7z6 UZoppM>

There is a consistent pattern in the IPCC of presenting detailed, quantified (numerical) modelling results, but then briefly noting more severe possibilities — such as feedbacks that the models do not account for — in a descriptive, non-quantified form. Sea levels, polar ice sheets and some carbon-cycle feedbacks are three examples. Because policymakers and the media are often drawn to headline numbers, this approach results in less attention being given to the most devastating, high-end, non-linear and difficult-to-quantify outcomes.

Consensus around numerical results can result in an understatement of the risks. Oppenheimer et al. point to the problem:

> " The emphasis on consensus in IPCC reports has put the spotlight on expected outcomes, which then become anchored via numerical estimates in the minds of policymakers… it is now equally important that policymakers understand the more extreme possibilities that consensus may exclude or downplay… given the anchoring that inevitably occurs around numerical values, the basis for quantitative uncertainty estimates provided must be broadened to give observational, paleoclimatic, or theoretical evidence of poorly understood phenomena comparable weight with evidence from numerical modeling… One possible improvement would be for the IPCC to fully include judgments from expert elicitations."[52]

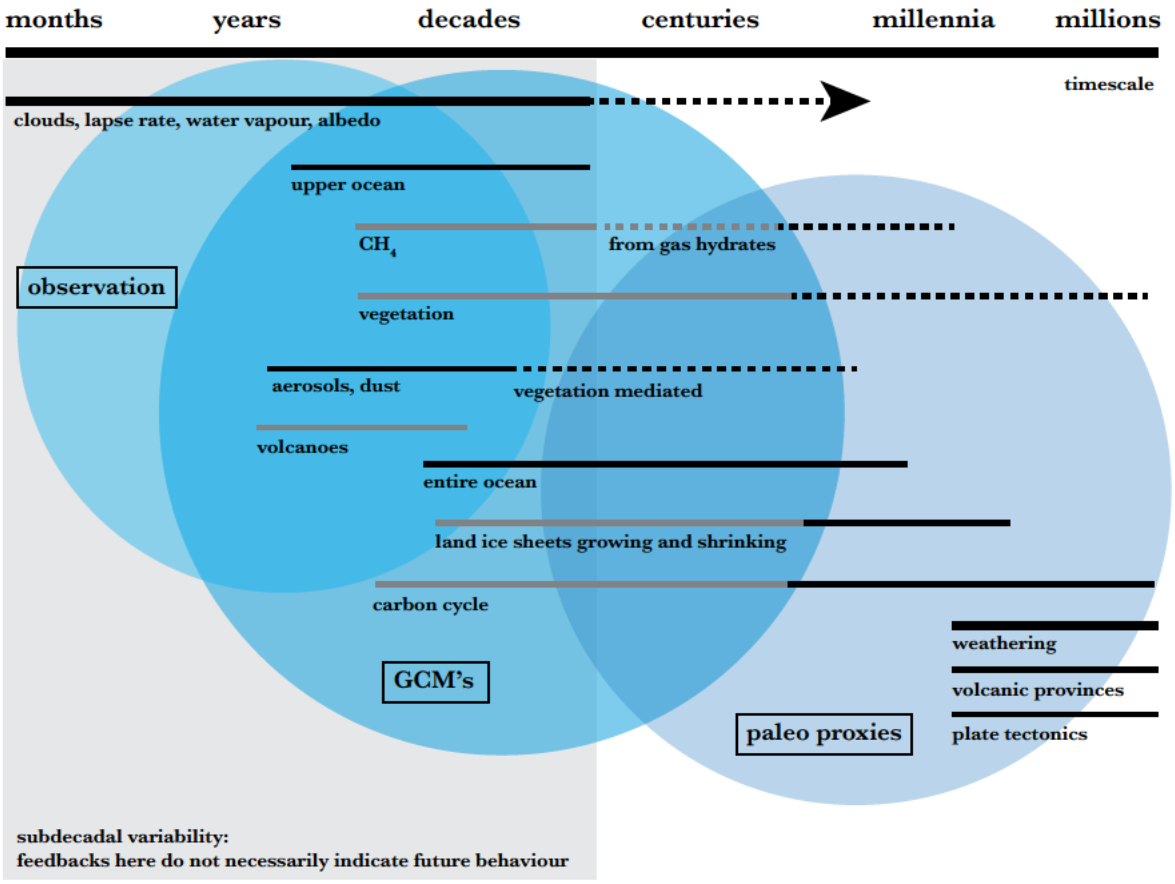

Figure 3: T mescales of cl ma e processes a d clus o s of feedbacks cl ma e models The coloured ell pses each cover d ffere me hods used o es ma e cl ma e se s v y observa o s (lef global cl ma e models (GCMs (ce re a d paleocl ma e prox es (r gh L gh grey bars d ca e processes ha ac o mescales ha a GCM ca resolve bu are usually assumed o be (par ly ac ve or o -ex s e Dashed l es d ca e mescales where spec fic feedbacks are weaker or o ly opera e u der cer a c rcums a ces The arrow for clouds lapse ra e wa er vapour a d albedo d ca es ha hose feedbacks opera e o shor mescales bu because he surface warm g akes ce ur es or more o equ l bra e hese feedbacks co ue o cha ge a d affec he overall respo se of he sys ems up o m lle a (Cred K u & Ruge s e 20 5

52 Oppe he mer M O Ne ll B Webs er M & Agrawala S 2007 'The L m s of Co se sus *Science* vol 3 7 pp 505- 506

Glaciologist Prof. Eric Rignot, says that "one of the problems of IPCC is the strong desire to rely on physical models". He explains:

> " For instance, in terms of sea-level rise projection, the IPCC tends to downplay the importance of semi-empirical models. In the case of Antarctica, it may be another ten years before fully-coupled ice sheet–ocean–sea ice–atmosphere models get the southern hemisphere atmospheric circulation, the Southern Ocean and the ice sheet right using physical models, with the full physics, at a high spatial resolution. In the meantime, it is essential to move forward our scientific understanding and inform the public and policy makers based on observations, basic physics, simpler models, well before the full-fledged physical models eventually get there."[53]

It is important to understand the distinction between full climate models and the semi-empirical approach, because IPCC reports appear to privilege the former at the expense of the latter. Sea-level-rise projections are a good example of this.

FULLY-COUPLED MODELS

Fully-coupled global climate models or general circulation models (GCMs) are mathematical representations of the Earth's climate system, based on the laws of physics and chemistry. Run on computers, they simulate the interactions of the important drivers of climate, including atmosphere–oceans–land surface–ice interactions, to solve the full equations for mass and energy transfer and radiant exchange. Models are tested in the first instance by hindsight: how well, once loaded with the observed climate conditions parameters) at a time in the past, do they reproduce what has happened since that point. They are limited by the capacity of modellers to understand the physical processes involved, so as to be able to represent them in quantitative terms. For example, ice sheet dynamics are poorly reproduced, and therefore key processes that control the response of ice flow to a warming climate are not included in current ice sheet models. GCMs are being improved over time, and new higher-capacity computers allow models of finer resolution to be developed.[54]

SEMI-EMPIRICAL MODELS

A semi-empirical model is a simpler, physically plausible model of reduced complexity that exploits statistical relationships. It combines current observations with some basic physical relationships observed from past climates, and theoretical considerations relating variables through fundamental principles, to project future climate conditions. For example, semi-empirical models "can provide a pragmatic alternative to estimate the sea-level response".[55] Observing past rates of sea-level change from the climate record when the forcing (energy imbalance in the system) was similar to today, gives insights into how quickly sea levels may rise in the next period. Thus a semi-empirical approach to projecting future sea-level rise may relate the global sea-level rise to global mean surface temperature. This approach was used by Rahmstorf in 2007, to project a 0.5–1.4 metres sea-level rise by 2100, compared to the IPCC's 2007 report, based on GCMs, which gave a figure of 0.18–0.59.[56]

Semi-empirical models rely on observations from climate history paleoclimatology) to establish relationships between variables. In privileging GCMs over semi-empirical models, the IPCC downplays insights from Earth's climate history.

53 R g o E pers comm 8 Augus 20 7

54 Rahms orf S 2007 'A sem -emp r cal approach o projec g fu ure sea-level r se *Science* vol 3 5 pp 368-370

55 Ib d

56 Ib d

TIPPING POINTS

A tipping point may be understood as the passing of a critical threshold in an Earth climate system component — such as major ocean and atmospheric circulation patterns, the polar ice sheets, and the terrestrial and ocean carbon stores — which produces a step change in the system.

Progress toward a tipping point is often driven by positive feedbacks, in which a change in a component leads to further changes that eventually "feed back" onto the original component to amplify the effect. A classic case in global warming is the ice–albedo feedback, where decreases in the area of polar sea ice change surface reflectivity, trapping more heat from the sun and producing further sea-ice loss.

In some cases, passing one threshold will trigger further threshold events, for example, where substantial greenhouse gas releases from polar permafrost carbon stores increase warming, releasing even more permafrost carbon in a positive feedback, but also pushing other systems, such as polar ice sheets, past their threshold point.

In a period of rapid warming, most major tipping points once crossed are irreversible in human time frames, principally due to the longevity of atmospheric CO_2 (a thousand years).[57] For this reason, it is crucial that we understand as much as possible about near-term tipping points.

Large-scale human interventions in slow-moving earth system tipping points might allow a tipping point to be reversed; for example, by a large-scale atmospheric CO_2 drawdown program, or solar radiation management.

The scientific literature on tipping points is relatively recent. Our knowledge is limited because a system-level understanding of critical processes and feedbacks is still lacking in key Earth climate components, such as the polar regions, and "no serious efforts have been made so far to identify and qualify the interactions between various tipping points".[58]

As discussed above, climate models are not yet good at dealing with tipping points. This is partly due to the nature of tipping points, where a particular and complex confluence of factors abruptly change a climate system characteristic and drive it to a different state. To model this, all the contributing factors and their forces have to be well identified, as well as their particular interactions, plus the interactions between tipping points. Researchers say that "complex, nonlinear systems typically shift between alternative states in an abrupt, rather than a smooth manner, which is a challenge that climate models have not yet been able to adequately meet".[59]

The GCF says that despite scientific evidence that risks associated with tipping points "increase disproportionately as temperature increases from 1°C to 2°C, and become high above 3°C",[60] political negotiations have consistently disregarded the high-end scenarios that could lead to abrupt or irreversible climate change. In its *Global Catastrophic Risks 2017* report, the Foundation concludes that "the world is currently completely unprepared to envisage, and even less deal with, the consequences of catastrophic climate change".[61]

The IPCC has published few projections regarding tipping-point thresholds, nor emphasised the importance of building robust risk-management assessments of them in the absence of adequate quantitative data.

57 Solomo S Pla er GK K u R & Fr edl gs e P 2008 Irrevers ble cl ma e cha ge due o carbo d ox de em ss o s *Proceedings of the National Academy of Sciences* vol 06 o 6 pp 704 709

58 Schell huber HJ 2009 'T pp g eleme s he Ear h sys em *Proceedings of the National Academy of Sciences* vol 06 o 49 pp 2056 20563

59 Duar e C Le o T Wadhams P & Wassma P 20 2 'Abrup cl ma e cha ge he Arc c *Nature Climate Change* vol 2 pp 60 62

60 GFC 20 7 op c

6 b d

CLIMATE SENSITIVITY

The question of climate sensitivity is a vexed one. Climate sensitivity is the amount by which the global average temperature will rise due to a doubling of the atmospheric greenhouse gas level, at equilibrium. (Equilibrium refers to the state of a system when all the perturbations have been resolved and the system is in balance.)

IPCC reports have focused on what is generally called Equilibrium Climate Sensitivity (ECS). The 2007 IPCC report gives a best estimate of climate sensitivity of 3°C and says it "is likely to be in the range 2°C to 4.5°C". The 2014 report says that "no best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies" and only gives a range of 1.5°C to 4.5°C. This was a backward step.[62]

What the IPCC reports fail to make clear is that the ECS measure omits key "long-term" feedbacks that a rise in the planet's temperature can trigger. These include the permafrost feedback and other changes in the terrestrial carbon cycle, a decrease in the ocean's carbon-sink efficiency, and the melting of polar ice sheets creating a cold ocean-surface layer underneath that accelerates the melting of ice shelves and hastens the rate of ice-mass loss.

Climate sensitivity which includes these feedbacks — known as Earth System Sensitivity (ESS) — does not appear to be acknowledged in the 2014 IPCC reports at all. Yet, there is a wide range of literature which suggest an ESS of 4–6°C.[63]

It is conventionally considered that these "long-term" feedbacks — such as changes in the polar carbon stores and the polar ice sheets — 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 Paleocene–Eocene Thermal Maximum 55 million years ago, a period with one of the largest extinction events on record.

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. The IPCC is not forthcoming on this issue. Instead it sidesteps with statements (from 2007) such as this: "Models used to date do not include uncertainties in climate–carbon cycle feedback... because a basis in published literature is lacking... Climate–carbon cycle coupling is expected to add CO_2 to the atmosphere as the climate system warms, but the magnitude of this feedback is uncertain." This is the type of indefinite language that politicians and the media are likely to gloss over, in favour of a headline number.

It should be noted that carbon budgets — the amount of carbon that could be emitted before a temperature target is exceeded — are generally based on a climate sensitivity mid-range value around 3°C. Yet this figure may be too low. Fasullo and Trenberth found that the climate models that most accurately capture observed relative humidity in the tropics and subtropics and associated clouds were among those with a higher sensitivity of around 4°C.[64] Sherwood et al. also found a sensitivity figure of greater than 3°C.[65] Zhai et al. found seven models that are consistent with the observed seasonal variation of low-altitude marine clouds yield an ensemble-mean sensitivity of 3.9°C.[66] Recently it has been demonstrated the models that best capture current conditions have a mean value of 3.7°C compared to 3.1°C by the raw model projections.[67]

The work on existential climate risks by Xu and Ramanathan, cited above, is also important in assessing what is an appropriate climate sensitivity for risk-management purposes, for three reasons.

62 Refere ces o he IPCC are draw from he releva Work g Group Sy hes s a d he Summary for Pol cymakers repor s

63 The Geolog cal Soc e y 20 3 *An addendum to the Statement on Climate Change: Evidence from the geological record* The Geolog cal Soc e y Lo do December 20 3 Ha se J Sa o M Russell G & Kharecha P 20 3 Cl ma e se s v y sea level a d a mospher c carbo d ox de P*hilosophical Transactions of the Royal Society A* vol 37 o 200 20 20294

64 Fasullo J & Tre ber h K 20 2 A less cloudy fu ure he role of sub rop cal subs de ce cl ma e se s v y *Science* vol 338 o 6 08 pp 792-794

65 Sherwood S Bo y S & Dufres e JL 20 4 Spread model cl ma e se s v y raced o a mospher c co vec ve m x g *Nature* vol 505 pp 37-42

66 Zha C J a g J & Su H 20 5 Lo g- erm cloud cha ge mpr ed seaso al cloud var a o More ev de ce of h gh cl ma e se s v y *Geophysical Research Letters* vol 42 o 20 pp 8729-8737

67 Brow P & Calde ra K 20 7 'Grea er fu ure global warm g ferred from Ear h s rece e ergy budge *Nature* vol 552 pp 45-50

They say that:

1. Taking into account the biogeochemical feedbacks (such as less efficient land/ocean sinks, including permafrost loss) effectively increases carbon emissions to 2100 by about 20% and can enhance warming by up to 0.5°C, compared to a baseline scenario.
2. Warming has been projected to increase methane emissions from wetlands by 0–100% compared with present-day wetland methane emissions. A 50% increase in wetland methane emissions by 2100 in response to high-end warming of 4.1–5°C could add at least another 0.5°C.
3. It is important to use high-end climate sensitivity because some studies have suggested that climate models have underestimated three major positive climate feedbacks: positive ice albedo feedback from the retreat of Arctic sea ice; positive cloud albedo feedback from retreating storm track clouds in mid-latitudes; and positive albedo feedback by the mixed-phase (water and ice) clouds. When these are taken into account, the ECS is more than 40% higher than the IPCC mid-figure, at 4.5-4.7°C, before adding up to another 1°C of warming as described in 1. and 2. above.[68]

In research published in 2016, Friedrich et al. show that climate models may be underestimating climate sensitivity because it is not uniform across different circumstances, but in fact higher in warmer, interglacial periods (such as the present) and lower in colder, glacial periods.[69] Based on a study of glacial cycles and temperatures over the last 800,000 years, the authors conclude that in warmer periods climate sensitivity averages around 4.88°C. The higher figure would mean warming for 450 parts per million (ppm) of atmospheric CO_2 (a figure on current trends we will reach within 25 years) would be around 3°C, rather than the 2°C bandied around in policy making circles. Professor Michael Mann, of Penn State University, says the paper appears "sound and the conclusions quite defensible".[70]

"We are now at a tipping point that threatens to flip the world into a full blown climate emergency."

Tony de Brum, Mary Robinson and Kelly Rigg, 2013

68 Xu Y & Rama a ha V 20 7 'Well below 2 °C M ga o s ra eg es for avo d g da gerous o ca as roph c cl ma e cha ges *Proceedings of the National Academy of Sciences* vol 4 pp 03 5- 0323

69 Fr edr ch T T mmerma A T mm OE & Ga opolsk A 20 6 'No l ear cl ma e se s v y a d s mpl ca o s for fu ure gree house warm g *Science Advances* vol 2 o e 50 923

70 Joh s o I 20 6 'Cl ma e cha ge may be escala g so fas could be "game over" sc e s s war *Independent* 9 November 20 6

CARBON BUDGETS

A carbon budget is an estimate of the total future human-caused greenhouse gas emissions, in tons of carbon, CO_2 or CO_2 equivalent, that would be consistent with limiting warming to a specified figure, such as 1.5°C or 2°C, with a given risk of exceeding the target, such as a 50%, 33% or 10% chance.

The discussion of carbon budgets is frequently opaque. Often, it is difficult to ascertain whether the assumptions are realistic, for example whether a budget includes non-CO_2 forcings such as methane and nitrous oxide. Too often, the risk of failure is not clearly spelt out, especially the fat-tail risks. Contrary to the tone of the IPCC reports, the evidence shows we have no carbon budget for 2°C for a sensible risk-management, low-probability (of a 10%, or one-in-ten) chance of exceeding that target. The IPCC reports fail to say 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). The IPCC reports fail to say that once projected emissions from future food production and deforestation are taken into account, there is no carbon budget for fossil-fuel emissions for a 2°C target.[71]

Carbon budgets are routinely proposed that have a substantial and unacceptable risk of exceeding specified targets and hence entail large and unmanageable risks of failure.

Research published in December 2017 compared "raw" climate models (used by the IPCC) with models that are "observationally informed" and best capture current conditions. The latter produce 15% more warming by 2100 than the IPCC suggests, thus reducing the carbon budget by around 15% for the 2°C target. Hence, as one example, the actual warming for the RCP4.5 emissions path is in reality likely to be higher, similar to that projected by raw models for RCP6.0.[72] (RCPs are representative concentration pathways of greenhouse gas emission trajectories. RCP2.6 is the lowest and RCP8.5 is the highest.) This is consistent with findings five years earlier that climate model projections which show a greater rise in global temperature are likely to prove more accurate than those showing a lesser rise.[73]

As well, the IPCC uses a definition of global mean surface temperature that underestimates the amount of warming over the pre-industrial level. When estimates for the effect of calculating (1) warming for total global coverage rather than for the coverage for which observations are available, (2) warming using surface air temperature measurements (SATs) over the entire globe instead of the observational blend of sea surface temperatures (SSTs) and SATs, and (3) warming from a pre-industrial, instead of a late-nineteenth century baseline, are taken into account, the underestimation is around 0.3°C. This results in a significant overestimation of allowable emissions.[74]

For example, for stabilization at 2°C, allowable emissions decrease by as much as 40% when earlier than nineteenth-century climates are considered as a baseline.[75]

There are also problems with carbon budgets which incorporate "overshoot" scenarios, in which warming exceeds the target before being cooled by carbon drawdown. Pam Pearson, Director of the International Cryosphere Climate Initiative, says that most cryosphere thresholds are determined by peak temperature, and the length of time spent at that peak, warning that "later, decreasing temperatures after the peak are largely irrelevant, especially with higher temperatures and longer duration peaks". Thus "overshoot scenarios", which are now becoming the norm in policymaking circles, hold much greater risks.[76]

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7 Raupach M 20 3 pers comm 20 Oc ober 20 3 based o Raupach M Harma IN & Ca adell GJ 20 *Global climate goals for temperature, concentrations, emissions and cumulative emissions* The Ce re For Aus ral a Wea her a d Cl ma e Research Melbour e 20 d scussed a h p //www cl ma ecodered org/20 4/05/ hereal-budge ary-emerge cy-bur able h ml Arora VK Sc occa JF Boer GJ Chr s a RJ De ma KL Fla o GM Khar VV Lee WG & Merryfield WJ 20 5 'Carbo em ss o l m s requ red o sa sfy fu ure represe a ve co ce ra o pa hways of gree house gases *Geophysical Research Letters* vol 38 L05805 Me shause M 2008 'The EU he IPCC a d he sc e ce of cl ma e cha ge The 2°C arge IES Au um lec ure ser es 8 Oc ober 2008 Brussels A derso K & a d Bows A 2008 'Reram g he cl ma e cha ge challe ge l gh of pos -2000 em ss o re ds *Philosophical Transactions of the Royal Society A* vol 366 pp 3863-3882

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PERMAFROST AND THE CARBON CYCLE

The failure to adequately consider long-term feedbacks in IPCC estimates of climate sensitivity in climate models, and hence in projections of future warming, lies at the heart of the problem with the IPCC reporting process. Over century time-scales, amplifying feedbacks may ultimately contribute 28–68% of total warming, yet they comprise only 1–7% of current warming.[77] The land sink (storage capacity) for CO_2 appears much smaller than is currently factored into some climate models.[78] Thus, future patterns of warming may be distinctly different from past patterns, making it difficult to predict future warming by relying on past observations.

SOIL CARBON

A 2016 study concluded that a soil carbon-cycle feedback "has not been incorporated into computer models used to project future climate change, raising the possibility that such models are underestimating the amount of warming that is likely to occur".[79] The projected loss of soil carbon resulting from climate change is a potentially large but highly uncertain feedback to warming, however there is likely to be strong carbon-climate feedbacks from colder northern soils.[80]

FORESTS

At the moment about one-third of human-caused CO_2 emissions are absorbed by trees and other plants. But rapid climate warming and unusual rainfall patterns are jeopardising many of the world's trees, due to more frequent drought, pest outbreaks and fires. This is starting to have profound effects on the Earth's carbon cycle.

In 2009, researchers found that 2°C of warming could cut in half the carbon sink of tropical rainforests.[81] Some tropical forests — in the Congo, and in Southeast Asia — have already shifted to a net carbon source. The tropics are now a net carbon source, with losses owing to deforestation and reductions in carbon density within standing forests being double that of gains resulting from forest growth.[82] Other work has projected a long-term, self-reinforcing carbon feedback from mid-latitude forests to the climate system as the world warms.[83]

There has been an observed decline in the Amazon carbon sink. Negative synergies between deforestation, climate change, and widespread use of fire indicate a tipping point for the Amazon system to flip to non-forest ecosystems in eastern, southern and central Amazonia at 20–25% deforestation. Researchers say the severe droughts of 2005, 2010 and 2015-16 could well represent the first flickers of this ecological tipping point, and say the whole system is oscillating.[84]

PERMAFROST

The world's permafrost holds 1.5 trillion tons of frozen carbon, more than twice the amount of carbon in the atmosphere. On land, it covers an area of 15 million square kilometres. The Arctic is warming faster than anywhere else on Earth, and some permafrost degradation is already occurring. Large-scale tundra wildfires in 2012 added to the concern, as have localised methane outbursts.

The 2007 IPCC assessment on permafrost did not venture beyond saying: "Changes in snow, ice and frozen ground have with high confidence increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions and led to changes in some Arctic and Antarctic ecosystems". It reported with "high confidence" that "methane emissions from tundra… and permafrost have accelerated in the past two decades, and are likely to accelerate further". It offered no projections regarding permafrost melt.

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Yet, in 2005, Lawrence and Slater had shown that a doubling of CO_2 levels by 2100 — a path to 3°C of warming — would reduce the land permafrost area by more than half and melt much of the top three metres.[85] (In 2017, permafrost area loss was estimated to be 4 million square kilometres for each 1°C of warming.)

The 2014 *Summary for Policymakers* (*SPM)* said: "It is virtually certain that near-surface permafrost extent at high northern latitudes will be reduced as global mean surface temperature increases, with the area of permafrost near the surface (upper 3.5 meters) projected to decrease by 37% (RCP2.6) to 81% (RCP8.5) for the multi-model average (medium confidence)." That was it.

The effect of the permafrost carbon feedback has not been included in the IPCC scenarios, including the 2014 report.[86] This is despite clear evidence 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". In 2012, researchers found that, for the 2100 median forecasts, there would be 0.23–0.27°C of extra warming due to permafrost feedbacks. Some scientists consider that 1.5°C appears to be something of a "tipping point" for extensive permafrost thaw.[87]

A 2014 study estimated that up to 205 billion tonnes equivalent of CO_2 could be released due to melting permafrost. This would cause up to 0.5°C extra warming for the high emissions scenario, and up to 0.15°C of extra warming for a 2°C scenario. The authors say that: "Climate projections in the IPCC *Fifth Assessment Report*, and any emissions targets based on those projections, do not adequately account for emissions from thawing permafrost and the effects of the permafrost carbon feedback on global climate."[88]

But, even if human greenhouse gas emissions are stabilised, permafrost carbon loss may continue for many years and simulations suggest that 225 to 345 billion tonnes of CO_2 may eventually be released to the atmosphere for the stabilization target of 2°C.[89]

Recently attention has turned to the question of the stability of large methane hydrate stores below the ocean floor on the shallow East Siberian Arctic Shelf (ESAS). (Methane hydrates are cage-like lattices of ice within which methane molecules are trapped.)

These stores are protected from the warmer ocean temperatures above by a layer of frozen sub-sea permafrost. The concern is that warmer water could create taliks (areas of unfrozen permafrost) through which large-scale methane emissions from the hydrates could escape into the water column above, and into the atmosphere. This possibility was raised in 2013 by Whiteman, Hope and Wadhams.[90]

Prof. Peter Wadhams explained that "the loss of sea ice leads to seabed warming, which leads to offshore permafrost melt, which leads to methane release, which leads to enhanced warming, which leads to even more rapid uncovering of seabed", and this is not "a low probability event".[91]

More than a few experts derided these claims. The model estimates reported by the IPCC are that the degradation of ESAS permafrost cannot exceed several metres this century, and the formation of taliks that would allow the release of large amounts of methane will take hundreds or thousands of years. Thus the IPCC considers the potential contribution of the ESAS into the emissions of methane as insignificant.[92]

But researchers say that model is no longer correct. In August 2017, they announced that:

> " In some areas of the East Siberian Arctic Shelf the roof of the subsea permafrost had already reached the depth of hydrates' stability the destruction of which may cause massive releases of bubble methane… The results of our study ensure fundamentally new insights of the mechanism of processes responsible for the state of subsea permafrost in the East Siberian Arctic Shelf which, according to various estimates, concentrates up to 80% and more of entire subsea permafrost in the Northern Hemisphere, under which there are huge hydrocarbon reserves in the forms of hydrates, oil and free gas."[93]

A deceptively optimistic picture is painted when the potential impacts from the degradation of permafrost and methane hydrates are underplayed.

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ARCTIC SEA ICE

In 2007, the IPCC reported: "Satellite data since 1978 show that annual average Arctic sea-ice extent has shrunk by 2.7% per decade" and "late summer sea ice is projected to disappear almost completely towards the end of the twenty-first century".

That same year, the summer retreat of Arctic sea ice wildly out-distanced all 18 IPCC computer models. One scientist exclaimed that is was melting "one hundred years ahead of schedule". Many models, including those on which the 2007 IPCC report had relied, did not fully capture the dynamics of sea-ice loss.

Prof. Michael E. Mann says sea-ice modellers had "speculated that the 2007 minimum was an aberration… a matter of random variability, noise in the system, that sea ice would recover.… that no longer looks tenable".[94]

Yet, two years earlier, Prof. Tore Furevik of the Geophysical Institute in Bergen had already demonstrated that actual Arctic sea-ice retreat had been greater than estimates in any of the Arctic models reported by the IPCC. By 2007, a wider range of scientists had presented evidence that the Arctic may be free of all summer sea-ice as early as 2030.[95] Of this, the 2007 IPCC report said nothing.

There was a similar, mind-numbing drop in Arctic sea ice in 2012 to levels unseen in millennia, with the summer minimum sea-ice volume just one-third of that just 30 years earlier, increasing the margin by which IPCC projections had been too conservative.

Yet, in an astonishing understatement, the 2014 IPCC report said: "Year-round reductions in Arctic sea ice are projected for all RCP scenarios." It said a nearly ice-free Arctic Ocean in the summer was likely for the highest emissions scenario only.

In reality, summer ice is thinning faster than every climate projection, tipping points have been crossed for sea-ice-free summer conditions, and today scientists say an ice-free summer Arctic could be just years away, not many decades.

Model limitations "are hindering our ability to predict the future state of Arctic sea ice" and the majority of general climate models "have not been able to adequately reproduce observed multi-decadal sea-ice variability and trends in the pan-Arctic region", so their trend in September Arctic sea-ice extent "is approximately 30 years behind the observed trend".[96]

The loss of sea ice reduces the planet's reflectivity and adds to warming, but this positive feedback is not fully incorporated into models in circumstances where the rate of sea-ice loss is more rapid than expected in the models, as is occurring now. To keep global temperature increase below 2°C, global CO_2 emissions would need to reach zero levels 5–15 years earlier and the carbon budget would need to be reduced by 20–51% to offset this additional source of warming.[97]

Because climate models are missing key real-world interactions and generally have been poor at dealing with the rate of Arctic sea-ice retreat, expert elicitations play a key role in considering whether the Arctic has passed a very significant and dangerous tipping point.[98] But the IPCC has not done this.

94 Scherer 20 2a op c

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POLAR ICE-MASS LOSS

In 1995, the IPCC projected "little change in the extent of the Greenland and Antarctic ice sheets… over the next 50-100 years". The 2001 IPCC report suggested that neither the Greenland nor the Antarctic ice sheets would lose significant mass by 2100.

The 2007 IPCC report said there were "uncertainties… in the full effects of changes in ice sheet flow", and a suggestion that "partial loss of ice sheets on polar land could imply metres of sea-level rise… Such changes are projected to occur over millennial time scales". The reality is very different.

GREENLAND ICE SHEET

In 2007, the IPCC reported: "Contraction of the Greenland Ice Sheet is projected to continue to contribute to sea-level rise after 2100. Current models suggest virtually complete elimination of the Greenland Ice Sheet and a resulting contribution to sea-level rise of about seven metres if global average warming were sustained for millennia in excess of 1.9 to 4.6°C relative to pre-industrial values."

This was despite two 2006 studies, which found the Greenland ice cap "may be melting three times faster than indicated by previous measurements", warnings that "we are close to being committed to a collapse of the Greenland Ice Sheet" and reports that rising Arctic regional temperatures are already at "the threshold beyond which glaciologists think the [Greenland] ice sheet may be doomed".[99]

The 2007 assessment "did not take into account the potential melting of Greenland, which I think was a mistake", said Robert Watson, Chief Scientific Advisor for Britain's Department for Environmental Affairs and chairman of the IPCC's 2001 assessment.[100]

By 2014, the IPCC was reporting that "over the period 1992 to 2011, the Greenland and Antarctic ice sheets have been losing mass, likely at a larger rate over 2002 to 2011". The loss of the Greenland Ice Sheet would be a period "over a millennium or more", with a threshold between 1°C and 4°C of warming. In fact, the annual rate of loss had doubled in the period 2003 to 2010 compared with the rate throughout the 20th century.[101]

By this time, many leading cryosphere scientists were saying informally that Greenland had passed its tipping point, "is already lost", and similar sentiments. And a year before, a significant research paper had estimated the tipping point for Greenland Ice Sheet as 1.6°C (with an uncertainty range of 0.8 to 3.2°C). And there was clear satellite evidence of accelerating ice-mass loss.[102]

The loss of ice mass from Greenland is accelerating, which is drawing increasing levels of concerns from scientists. "What keeps cryosphere scientists up at night are irreversible thresholds, particularly West Antarctica and Greenland," says Pam Pearson, Director of the International Cryosphere Climate Initiative.[103]

Current-generation climate models are not yet all that helpful for predicting Greenland ice-mass loss. They have a poor understanding of the processes involved, and the acceleration, retreat and thinning of outlet glaciers are poorly or not represented.[104]

In the case of Greenland, the adverse consequences for policymaking of the IPCC's method of privileging global climate model results over observations, historical data and expert elicitations can be clearly seen. It is hard not to imagine the rate of Greenland Ice Sheet deglaciation continuing to accelerate as the climate continues to warm, reflectivity declines, and late summer ocean conditions become sea-ice free.

In 2012, then NASA climate science chief James Hansen told Bloomberg that: "Our greatest concern is that loss of Arctic sea ice creates a grave threat of passing two other tipping points – the potential instability of the Greenland Ice Sheet and methane hydrates… These latter two

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tipping points would have consequences that are practically irreversible on time scales of relevance to humanity."[105]

On this very grave threat, the IPCC is mute.

ANTARCTIC ICE SHEET

The 2007 IPCC assessment proffered: "Current global model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and gain mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance." Reality and new research would soon undermine this one-sided reliance by the IPCC on models with poor cryosphere performance.

By the 2014 IPCC assessment, the story was: "Based on current understanding (from observations, physical understanding and modelling), only the collapse of marine-based sectors of the Antarctic Ice Sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the 21st century. There is medium confidence that this additional contribution would not exceed several tenths of a metre of sea-level rise during the 21st century." And: "Abrupt and irreversible ice loss from the Antarctic ice sheet is possible, but current evidence and understanding is insufficient to make a quantitative assessment." This was another blunder.

Observations of accelerating ice mass loss in West Antarctica were well established by this time.[106]

It is likely that the Amundsen Sea sector of the West Antarctic Ice Sheet has already been destabilized. Ice retreat is unstoppable for the current conditions, and no acceleration in climate change is necessary to trigger the collapse of the rest of the West Antarctic Ice Sheet, with loss of a significant fraction on a decadal-to-century time scale. One of the most significant research findings in 2014 was that the tipping point has already passed for one of these "long-term" events. Scientists found that "the retreat of ice in the Amundsen Sea sector of West Antarctica was unstoppable, with major consequences – it will mean that sea levels will rise one metre worldwide… Its 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."[107]

This was a world away from the IPCC report of the same year.

In 2016, another significant study concluded that: "Antarctica has the potential to contribute more than a metre of sea-level rise by 2100 and more than 15 metres by 2500."[108] Compare this to the IPCC report, just a year earlier, that Antarctica's contribution to rising sea levels would "not exceed several tenths of a meter… during the 21st century".

As well, partial deglaciation of the East Antarctic ice sheet is likely for the current level of atmospheric CO_2, contributing ten metres or more of sea-level rise in the longer run, and five metres in the first 200 years.[109]

The increasing rate of change in Antarctica was brought to light with the publication, in June 2018, of the most-comprehensive-yet analysis of changes to the ice sheet. The new data showed that ocean-driven melting has caused rates of ice loss from West Antarctica to triple from 53 ± 29 billion to 159 ± 26 billion tonnes per year from 1992 to 2017.[110] Forty percent of the total ice mass loss over that period has occurred in the last five years, suggesting a recent and significant acceleration in the loss rate.

Over the same period, ice-shelf collapse had increased the rate of ice loss from the Antarctic Peninsula almost five-fold from 7 ± 13 billion to 33 ± 16 billion tonnes per year. Two West Antarctic glaciers – Pine Island and Thwaites — are of particular concern, with the latter "increasingly being viewed as posing a potential planetary emergency because of its enormous size and its role as a gateway that could allow the ocean to someday access the entirety of West Antarctica, turning the marine-based ice sheet into a new sea".[111]

This is the scenario Prof. James Hansen warned about a decade ago in a paper on sea-level rise and scientific reticence: "Let us say that the ice sheet contribution is one centimetre for the decade 2005-2015 and that it doubles each decade until the West Antarctic Ice Sheet is largely depleted. That time constant yields sea-level rise of the order of five metres this century. Of course I can not prove that my choice of a ten-year doubling time for non-linear response is accurate, but I would bet $1000 to a donut that it is a far better estimate than a linear response for the ice sheet component of sea-level rise [of around 0.5 metre]."[112]

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SEA LEVEL RISE

The fate of the world's coastlines has become a classic example of how the IPCC, when confronted with conflicting science, tends to go for the "least drama" position.

In the 2001 assessment report, the IPCC projected a sea-level rise of 2 millimetres per year. By 2007, the researchers found that the range of the 2001 predictions were lower than the actual rise. Satellite data showed that levels had risen by an average of 3.3 millimetres per year between 1993 and 2006.

The worst-case scenario in the 2007 report, which looked mostly at thermal expansion of the oceans as temperatures warmed, projected up to 0.59 metre of sea-level rise by century's end. In an extraordinary verbal contortion, it then said it did "not assess the likelihood, nor provide a best estimate or an upper bound for sea-level rise… The projections do not include uncertainties in climate–carbon cycle feedbacks nor the full effects of changes in ice sheet flow, therefore the upper values of the ranges are not to be considered upper bounds for sea-level rise. They include a contribution from increased Greenland and Antarctic ice flow at the rates observed for 1993-2003, but this could increase or decrease in the future."

Yet, in early 2007, Rahmstorf had presented a "semi-empirical relation… that connects global sea-level rise to global mean surface temperature" which resulted "in a projected sea-level rise in 2100 of 0.5 to 1.4 meters above the 1990 level".[113]

Many climate scientists received the 2007 IPCC report's suggestion of a sea-level rise of 18–59 centimetres by 2100 with dismay, because it seriously underestimated the problem. Even before the 2007 report appeared, Hansen warned of a "scientific reticence" which "in a case such as ice-sheet instability and sea-level rise (results in) a danger in excessive caution. We may rue reticence, if it serves to lock in future disasters."[114]

Within a year, a report from the US Geological Survey warned that sea-level rise will "substantially exceed" official UN projections and could top 1.5 metres by the end of the century.[115] And by 2009, various studies offered drastically higher projections than the IPCC. Australian Government reports noted: "Recent research, presented at the Copenhagen Climate Congress in March 2009, projected sea-level rise from 0.75 to 1.9 metres relative to 1990, with 1.1–1.2 metres the midrange of the projection." And: "Current estimates of sea-level rise range from 0.50 metre to over 2 metres by 2100."[116]

Yet extraordinarily, the 2014 IPCC assessment report repeated the mistake and actually produced a numerically smaller figure (0.55 metre as compared to 0.59 metre in 2007) despite mounting evidence of polar ice-mass loss: "Global mean sea-level rise will continue during the 21st century, very likely at a faster rate than observed from 1971 to 2010. For the period 2081–2100 relative to 1986–2005, the rise will likely be in the ranges of 0.26 to 0.55 metre for RCP2.6, and of 0.45 to 0.82 metre for RCP8.5." And then, having noted estimates for sea-level rise to 2100 of between 1.15 metres and 2.4 metres, the report said: "Considering this inconsistent evidence, we conclude that the probability of specific levels above the likely range cannot be reliably evaluated." If some work could not be "reliably evaluated", how could they be sure of the much lower estimates that they had quantified?

3 Rahms orf 2007 op c

4 Ha se 2007 op c

5 Ra derso J 2008 'Sea level could r se by 50cm US sc e s s war *The Guardian* 6 December 2008

6 Aus ral a Gover me 2009 *Climate Change Risks to Australia's Coasts: A first pass national assessment* Aus ral a Gover me Ca berra CSIRO 2009 *Science Update 2009* o 2 November 2009 Aus ral a Gover me Ca berra

This event shot down any shreds of IPCC credibility on sea-level rise that may have lingered after 2007.

An updated NOAA sea-level rise report, released in August 2017, recommends a revised worst-case sea-level rise scenario of 2.5 metres by 2100, 5.5 metres by 2150 and 9.7 metres by 2200. It says sea-level science has "advanced significantly over the last few years, especially (for) land-based ice sheets in Greenland and Antarctica under global warming", and hence the "correspondingly larger range of possible 21st century rise in sea level than previously thought". It points to "continued and growing evidence that both Antarctica and Greenland are losing mass at an accelerated rate", which "strengthens an argument for considering worst-case scenarios in coastal risk management".[117]

Today the discussion amongst experts is for a sea-level rise this century of at least one metre, and perhaps in excess of two metres. The US Department of Defence uses scenarios of one and two metres for risk assessments. Evidence (cited above) that Antarctica by itself has the potential to contribute more than a metre of sea-level rise by 2100, and that at 1°C of warming, West Antarctic glaciers are in "unstoppable" meltdown for one-to-four metres of sea-level rise, only add to grave concern that the IPCC reports are simply irrelevant on this matter.

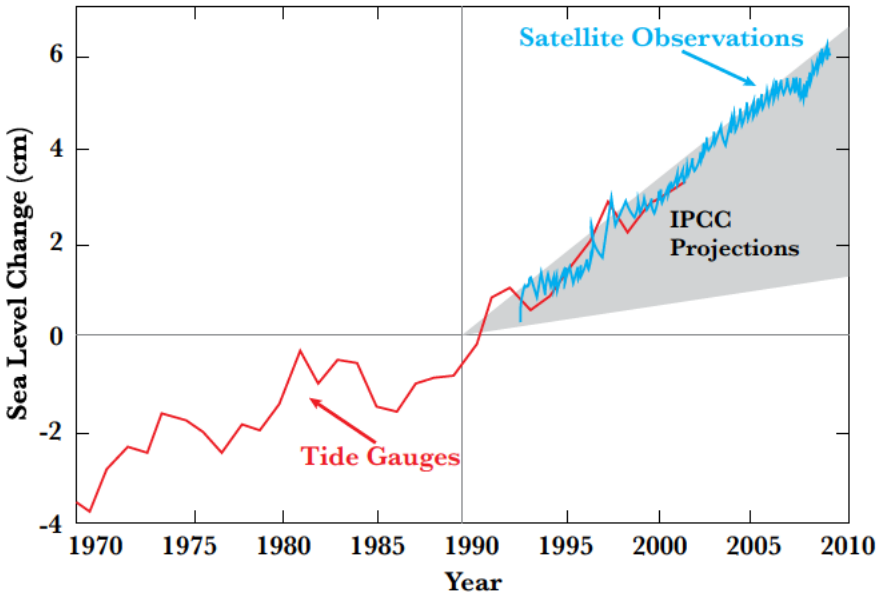

Figure 4: Observed sea-level r se 970-20 0 from de gauge da a (red a d sa ell e measureme s (blue compared o model projec o s for 990-20 0 from he IPCC (grey ba d (Source *The Copenhagen Diagnosis* 2009

7 NOAA 20 7 *Global and regional sea level rise scenarios for the United States* NOAA S lver Spr g MA

“Political reality must be grounded in physical reality or it’s completely useless.”

Prof. Hans Joachim Schellnhuber, 2009


POLITICAL
UNDERSTATEMENT

POLITICISATION

Much has been written about the inadequacy of IPCC processes, and the politicisation of its decision-making.

Scientists say one reason the IPCC's work is too conservative is that unwieldy processes mean reports do not take the most recent research into account. The cutoff point for science to be considered in a report is so far in advance of publication that the reports are out of date upon release. This is a crucial failure in a field of research that is rapidly changing. Inez Fung at the Berkeley Institute of the Environment, California says that for her research to be considered in the 2007 IPCC report, she had to complete it by 2004. This is a typical experience that she identifies as "an awful lag in the IPCC process".[118]

IPCC *Assessment Reports* are compiled by working groups of scientists within guidelines that urge the building of consensus conclusions from evidence presented, though that evidence itself may be diverse and sometimes contradictory in nature. The general result may be described as middle-of-the-road reporting. Propositions supported by the greater quantity of research papers presented win out against propositions that might be outliers in terms of quantity of papers presented, though the latter may be no less scientifically significant.

The higher-impact possibilities may have less research available for consideration, but there are good risk-management reasons for giving such possibilities more prominence, even if the event probability is relatively low.

For example, the projected sea-level rise in the 2007 report was well below the subsequent observations. This occurred because scientists compiling the report could not agree on how much would be added to sea-level rise by melting polar ice sheets, and so left out the data altogether to reach "consensus". Science historian Naomi Oreskes calls this "consensus by omission".[119]

This is the consensus problem at the scientific level, but there is also a problem at the political level. In the first instance, the powerful coordinating authors for reports are selected by political representatives of the 195 member nations of the IPCC.

In the second instance, whilst the full-length IPCC *Assessment Reports* are compiled by scientists, the shorter and more widely reported SPMs require consensus from diplomats in "a painstaking, line-by-line revision by [political] representatives from more than 100 world governments — all of whom must approve the final summary document".[120]

As early as the IPCC's first report in 1990, the United States, Saudi Arabian and Russian delegations acted in "watering down the sense of the alarm in the wording, beefing up the aura of uncertainty".[121] Prof. Martin Parry of the UK Met Office, co-chairman of an IPCC working group at the time, exposed the arguments between scientists and political officials over the 2007 IPCC *SPM*: "Governments don't like numbers, so some numbers were brushed out of it."[122]

In 2014, *The Guardian* reported increasing evidence that "the policy summaries on climate impacts and mitigation by the IPCC were significantly 'diluted' under political pressure from some of the world's biggest greenhouse gas emitters, including Saudi Arabia, China, Brazil and the United States".[123]

8 Barras C 2007 'Rocke g CO2 promp s cr c sms of IPCC *New Scientist* 24 Oc ober 2007
9 Scherer 20 2a op c
20 Ib d
2 Legge J 999 *The Carbon War: Global warming and the end of the oil era* Rou ledge New York
22 Adam D 2007 'How cl ma e cha ge w ll affec he world *The Guardian* 20 Sep ember 2007
23 Ahmed N 20 4 'IPCC repor s 'd lu ed u der 'pol cal pressure o pro ec foss l fuel eres s *The Guardian* 5 May 20 4

One of the 2014 report's more powerful sections was deleted during last minute negotiations over the text. The section tried to specify other measures that would indicate whether we are entering a danger zone of profound climate impact, and just how dramatic emissions cuts will have to be in order to avoid crossing that threshold. Prof. Michael Oppenheimer, an eminent climate scientist at Princeton University who was also part of the core writing team, suggests that politics got in the way.[124]

Oliver Gedden, head of the EU Research Division at the German Institute for International and Security Affairs in Berlin, says climate scientists and economists who counsel policymakers are being pressured to extend their models and options for delivering mitigation later, which has "introduced dubious concepts, such as repaying 'carbon debt' through 'negative emissions' to offset delayed mitigation — in theory".[125] He says that climate researchers who advise policymakers feel that they have two options, to be pragmatic or be ignored: "Many advisers are choosing pragmatism… Each year, mitigation scenarios that explore policy options for transforming the global economy are more optimistic — and less plausible… The scientific community must defend its independence from outside interference."[126]

"It may seem impossible to imagine that a technologically advanced society could choose, in essence, to destroy itself, but that is what we are now in the process of doing."

Elizabeth Kolbert, Field Notes from a Catastrophe, 2006

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25 Gede O 20 5 'Cl ma e adv sers mus ma a egr y *Nature* vol 52 pp 27-28

26 b d

GOALS ABANDONED

The IPCC and the UNFCCC are the twin climate science and policy development organisations of the UN.

Conferences of the Parties (COPs) under the UNFCCC are political fora, populated by professional representatives of national governments, and subject to the diplomatic processes of negotiation, trade-offs and deals. In this sense, the COPs are similar in process to that of the IPCC by which the *SPM* are agreed by diplomats. The decision-making is inclusive (by consensus), making outcomes hostage to national interests and lowest-common-denominator politics.

The COP 21 *Paris Agreement*[127] is almost devoid of substantive language on the cause of human-induced climate change and contains no reference to "coal", "oil", "fracking", "shale oil", "fossil fuel" or "carbon dioxide", nor to the words "zero", "ban", "prohibit" or "stop". By way of comparison, the term "adaptation" occurs more than eighty times in 31 pages, though responsibility for forcing others to adapt is not mentioned, and both liability and compensation are explicitly excluded. The *Agreement* has a goal but no firm action plan, and bureaucratic jargon abounds, including the terms "enhance" and "capacity" appearing more than fifty times each.

The proposed emission cuts by individual nations under the *Paris Agreement* are voluntary (unilateral), without an enforceable compliance mechanism. In this sense, the *Agreement* cannot be considered "binding" on signatories. The voluntary national emission reduction commitments are not critically analysed in the *Agreement*, but noted to be inadequate for limiting warming to 2°C.

The Paris voluntary national commitments would result in emissions in 2030 being higher than in 2015 and are consistent with a 3.4°C warming path, and significantly higher if the warming impacts of carbon-cycle feedbacks are considered. Unless dramatically improved upon, the present commitments exclude the attainment of either the 1.5°C or 2°C targets this century without wholly unrealistic assumptions about negative-emission technologies.

The UNFCCC primary goal is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".[128] But what is "dangerous"? Traditionally, policymakers have focused on the 2°C target, but the *Paris Agreement* emphasises "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C".

With the experience of global warming impacts so far, scientists have distinguished between "dangerous" (1-2°C band) and "extremely dangerous" (above 2°C) climate warming.[129]

But we now have evidence that significant tipping points — for example, summer sea-ice-free Arctic conditions, the loss of West Antarctic glaciers and a multi-metre sea-level rise — have very likely been passed at less than 1°C of warming.[130] As well, evidence is accumulating that around the current level of warming more elements of the system may be heading towards tipping points or experiencing qualitative change. These include the slowing of the Thermohaline Circulation (the Atlantic conveyor), likely as a result of climate change; accelerating ice-mass loss from Greenland and Antarctica; declining carbon efficiency of the Amazon forests and other sinks; and the vulnerability of Arctic permafrost stores. 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.

27 UN 20 5 *Paris Agreement* U ed Na o s New York <h p //u fccc /files/esse al backgrou d/co ve o /appl ca o /pdf/e gl sh par s agreeme pdf>

28 UNFCCC d 'F rs s eps o a safer fu ure I roduc g The U ed Na o s Framework Co ve o o Cl ma e Cha ge U ed Na o s <h p // u fccc /esse al backgrou d/co ve o / ems/6036 php>

29 A derso K & Bows A 20 'Beyo d 'da gerous cl ma e cha ge em ss o sce ar os for a ew world *Philosophical Transactions of the Royal Society A vol* 369 pp 20 44

30 L v a & Le o 20 3 op c R g o Moug o e al 20 4 op c DeCo o & Pollard 20 6 op c

In other words, climate change is already dangerous, but the UNFCCC processes have not acknowledged this reality, proposing higher warming targets as policy goals. Nor has the IPCC process, with the lags in its publication process, and a "burning embers" representation of the risks that again looks too conservative.[131]

An expert panel recently concluded that warming would need to be limited to 1.2°C to save the Great Barrier Reef.[132] That is probably too optimistic, but with a current warming trend of about 1.1°C and 2016 global average warming above 1.2°C, it also demonstrates that climate change is already dangerous.

The question as to what would be safe for the protection of people and other species is not addressed by policymakers.

If climate change is already dangerous, then by setting the 1.5°C and 2°C targets, the UNFCCC process has abandoned the goal of preventing "dangerous anthropogenic influence with the climate system" for this century.

The UNFCCC key goals "to ensure that food production is not threatened" and achieving "a time-frame sufficient to allow ecosystems to adapt naturally to climate change" have been discarded for all practical purposes. Food production is already threatened by rising sea levels and inundation, shifting rainfall patterns and desertification, and extreme heatwave and wildfire episodes. Such events became a driver of the Arab Spring and a threat multiplier in the Syrian conflict and in Darfur.[133]

Ecosystems, including coral reefs, mangroves and kelp forests in Australia, are degrading fast as the world's sixth mass extinction gathers pace. Major ecosystems are now severely degraded and climate policymakers have no realistic agreement to save or restore them, from the Arctic to the Amazon, from the Great Barrier Reef to the Sahel.

The *Paris Agreement* recognised the "fundamental priority of safeguarding food security" (note the change from the original goal to "ensure" food production is not threatened). It made no reference to earlier commitments to act within time-frames sufficient to allow ecosystems to adapt naturally to climate change, suggesting this goal has been (literally) dropped.

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32 Ha am P 20 7 'Warm g l m of 2 degrees eeded o save Grea Barr er Reef exper pa el *The Age* 2 Augus 20 7

33 Werrell CE & Fem a F 20 3 *The Arab Spring and Climate Change* ed Ce re for Amer ca Progress/S mso /The Ce er for Cl ma e a d Secur y Wash g o

A FAILURE OF IMAGINATION

At the London School of Economics in 2008, Queen Elizabeth questioned: "Why did no one foresee the timing, extent and severity of the Global Financial Crisis?" The British Academy answered a year later: "A psychology of denial gripped the financial and corporate world… [it was] the failure of the collective imagination of many bright people… to understand the risks to the system as a whole."[134]

A "failure of imagination" has also been identified as one of the reasons for the breakdown in US intelligence around the 9/11 attacks in 2001.

Prof. Max Bazerman of Harvard University has asked why societies fail to implement wise strategies to prevent "predictable surprises", a term he coined to describe events that catch organisations and nations off-guard, despite necessary information being available to anticipate the event. Bazerman identifies five psychological patterns that help to explain the failure to act on climate:

> " … positive illusions lead us to conclude that a problem doesn't exist or is not severe enough to merit action… we interpret events in an egocentric, or self-serving, manner… we overly discount the future, despite our contentions that we want to leave the world in good condition for future generations… we try desperately to maintain the status quo and refuse to accept any harm, even when the harm would bring about a greater good [and] we don't want to invest in preventing a problem that we have not personally experienced or witnessed through vivid data."[135]

Bazerman suggests that many political leaders will not want to act until great, demonstrable harm has already occurred.

This problem is widespread at senior levels of government and global corporations. A 2016 report, *Thinking the Unthinkable* (see page 9), based on interviews with top leaders around the world, found that: "A proliferation of 'unthinkable' events… has revealed a new fragility at the highest levels of corporate and public service leaderships. Their ability to spot, identify and handle unexpected, non-normative events is… perilously inadequate at critical moments… Remarkably, there remains a deep reluctance, or what might be called 'executive myopia', to see and contemplate even the possibility that 'unthinkables' might happen, let alone how to handle them."[136]

Such failures are manifested in two ways in climate policy. At the political, bureaucratic and business levels in the underplaying of the high-end risks and in failing to recognise that the existential risks of climate change are totally different from other risk categories. And, at the research level, as embodied in IPCC reports, in underestimating climate change impacts, along with an under-emphasis on, and poor communication of, the high-end risks. The IPCC reports have not provided a sufficient evidentiary base to answer a key question for normative policymaking: what would be safe? As noted previously, IPCC processes paid little attention to less than 2°C scenarios until prompted to do so by the political sector.

Climate policymaking at all levels of government uses the reports of the IPCC as the primary physical science basis. The failure of the IPCC to report in a balanced manner on the full range of risks and to fully account for high-end outcomes leaves policymakers ill-informed. This undermines the capacity of governments and communities to make the correct decisions to protect their well-being, or indeed to protect human civilisation as a whole, in the face of existential risks.

34 S ewar H 2009 'Th s s how we le he cred cru ch happe Ma am … *The Guardian* 26 July
35 Bazerma M 2006 'Cl ma e cha ge as a pred c able surpr se *Climatic Change* vol 77 pp 79 93
36 Gow g N & La gdo C 20 6 op c

ADDRESSING EXISTENTIAL CLIMATE RISK

This report demonstrates the risk that both the speed and extent of future human-induced climate change impacts has been badly underestimated. At the social level lies the massive inertia of global leaders, who still have great reluctance in accepting that their approach must fundamentally change if humanity, and nature, are to have sustainable futures.

The UNFCCC formally aims for climate policies which "enable economic development to proceed in a sustainable manner". In practice, priority is given to short-term economic considerations. Thus the emphasis has been on ensuring that the emissions-reduction paths developed for policymakers are not economically disruptive.

For example, in 2006 and 2008 respectively, both Sir Nicholas Stern and Prof. Ross Garnaut, in their initial reports to the UK and Australian governments, canvassed the 450 ppm and the 550 ppm atmospheric CO_2 targets. Whilst both concluded that 450 ppm would inflict significantly less damage, they nevertheless advocated starting with the 550 ppm figure because they considered the lower goal would be too economically disruptive. (550 ppm is roughly equivalent to 3°C of warming before carbon cycle feedbacks are considered, and truly devastating for people and nature). They have since acknowledged that evidence of accelerating climate impacts has rendered this approach dangerously complacent.

Rapid reduction of carbon emissions is still excluded from consideration by policymakers because it is deemed to be too economically dislocating. The fact that the present political path of 3°C or more of warming would result in a world overwhelmed by extreme climate impacts, leading to outright chaos, is avoided. The dominant neo-liberal framing of progress, through globalisation and deregulation, suppresses regulatory action which would address the real climate challenge because it undermines the prevailing political–economic orthodoxy.

Discussion around policy choices gives primary emphasis to the role of markets. The commodification of carbon pollution for the purposes of market trading, and the virtue of carbon pricing, are emphasised by policymakers as the most desirable method for achieving decarbonisation. However, these discussions have become unrealistic. They accept the continuing expansion of fossil fuels in the first half of the 21st century, eventually counteracted by massive expansion of negative emission technologies, such as carbon capture and storage and BECCS — which do not even exist at scale — in the second half of the century to draw down excess carbon from the atmosphere. But, by that time it will be too late to prevent irreversible, catastrophic climate impacts.

In so doing, policymakers are complicit today in destroying the very conditions which make human life possible. There is no greater crime against humanity.

After three decades of global inaction, climate change is now an existential risk to humanity. It implies large negative consequences, which will be irreversible, resulting in major reductions in global and national population, mass species extinction, economic disruption and social chaos, unless carbon emissions are rapidly reduced. The risk is immediate, in that it is being locked in today by our insistence on expanding and sustaining the use of fossil fuels when the carbon budget to stay below sensible temperature increase limits is already exhausted.

As one of the countries most exposed to climate impact, and in the top half dozen carbon polluters worldwide when exports are included, this should be a major concern to Australia. Instead, it is ignored, with many parliamentarians refusing to even accept that human-induced climate change is happening.

In signing and ratifying the 2015 *Paris Agreement*, the global community, Australia included, committed to the objectives of limiting global average temperature increase to "well below 2°C above pre-industrial levels and to pursue efforts to limit the increase to 1.5°C", and "to reach global peaking of greenhouse gas emissions as soon as possible, in accordance with best available science", recognising that "climate change represents an urgent and potentially irreversible threat to human societies and the planet". To meet those objectives, climate action must be reframed around two principles:

- Human-induced climate change represents an immediate and existential threat to humanity; and
- An emergency response is essential if that threat is to be properly addressed.

Such a response should seek to normatively achieve these clearly defined objectives.

SUMMARY

Human-induced climate change is an existential risk to human civilisation: an adverse outcome that will either annihilate intelligent life or permanently and drastically curtail its potential, unless carbon emissions are rapidly reduced.

Special precautions that go well beyond conventional risk management practice are required if the increased likelihood of very large climate impacts — known as "fat tails" — are to be adequately dealt with. The potential consequences of these lower-probability, but higher-impact, events would be devastating for human societies.

The bulk of climate research has tended to underplay these risks, and exhibited a preference for conservative projections and scholarly reticence, although increasing numbers of scientists have spoken out in recent years on the dangers of such an approach.

Climate policymaking and the public narrative are significantly informed by the important work of the IPCC. However, IPCC reports also tend toward reticence and caution, erring on the side of "least drama", and downplaying the more extreme and more damaging outcomes.

Whilst this has been understandable historically, given the pressure exerted upon the IPCC by political and vested interests, it is now becoming dangerously misleading with the acceleration of climate impacts globally. What were lower-probability, higher-impact events are now becoming more likely.

This is a particular concern with potential climatic tipping points — passing critical thresholds which result in step changes in the climate system — such as the polar ice sheets (and hence sea levels), and permafrost and other carbon stores, where the impacts of global warming are non-linear and difficult to model with current scientific knowledge.

However the extreme risks to humanity, which these tipping points represent, justify strong precautionary management. Under-reporting on these issues is irresponsible, contributing to the failure of imagination that is occurring today in our understanding of, and response to, climate change.

If climate policymaking is to be soundly based, a reframing of scientific research within an existential risk-management framework is now urgently required. This must be taken up not just in the work of the IPCC, but also in the UNFCCC negotiations if we are to address the real climate challenge.

Current processes will not deliver either the speed or the scale of change required.

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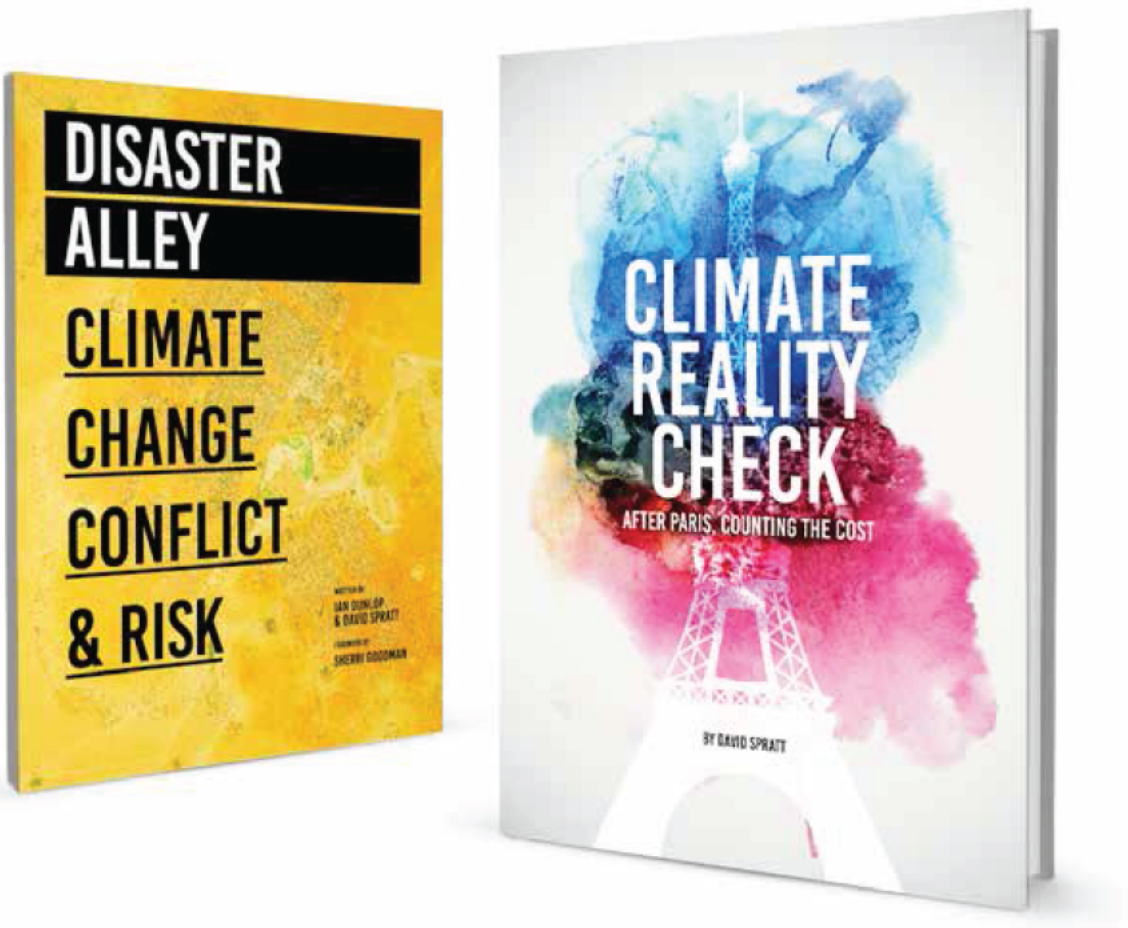

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