

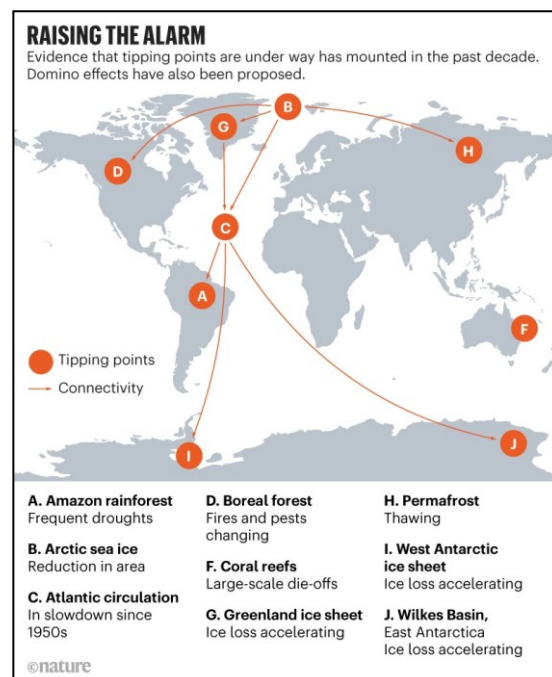
Impact case study (REF3)

Institution: University of Exeter		
Unit of Assessment: UoA 7 Earth Systems and Environmental Sciences		
Title of case study: Climate Tipping Points – Too Risky to Bet Against		
Period when the underpinning research was undertaken: 2011-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Tim Lenton	Professor & Director, Global Systems Institute	May 2011 - present
Lesley Allison	Research Fellow	September 2013 - May 2014
Chris Boulton	Postdoctoral Research Fellow	August 2015 - present
Period when the claimed impact occurred: 1 August 2013 - 31 Dec 2020		
Is this case study continued from a case study submitted in 2014? N		
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Avoiding dangerous climate change is the central goal of the United Nations Framework Convention on Climate Change (UNFCCC). Research by Prof Lenton and colleagues has identified how the risks posed by climate tipping points increase with global warming. This has influenced public policy both nationally and internationally by providing:</p> <ul style="list-style-type: none"> • Vital evidence underpinning goals to limit global warming to well below 2°C • Up to >8-fold increased estimates of the social cost of carbon • Adaptation advice to governments on tipping point risks and early warning systems <p>Exeter's research has also influenced public understanding, learning and participation by:</p> <ul style="list-style-type: none"> • Participation in news and television programmes with estimated viewing figures of 500 million • Stimulating public engagement through an online course with attendance of >13,000 • Contributing to a change in public perception and mood and the declaration of a Climate Emergency, with research extensively cited by newspapers and popular climate change movements such as Extinction Rebellion (coverage by >350 news outlets, 'most impactful' climate research paper of 2018). 		
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>Preventing “dangerous anthropogenic interference with the climate system” is the objective (Article 2) of the United Nations Framework Convention on Climate Change (UNFCCC), and a critical issue for societies worldwide.</p> <p>In 2008 Prof Tim Lenton, then at UEA, and colleagues published a seminal <i>PNAS</i> paper that identified ‘Tipping Elements in the Earth’s Climate System’. Building on this work upon moving to Exeter in 2011, Lenton’s team pioneered research to: (i) develop and test early warning methods for climate tipping points; (ii) quantify how the risks of reaching climate tipping points alter economic analyses of climate change; and (iii) assess how interactions between tipping points increase these risks, and the urgency of tackling climate change. Tipping elements are components of the Earth system, e.g. the West Antarctic Ice Sheet and the Amazon rainforest, which could be pushed beyond a tipping point where reinforcing feedbacks cause them to change state, often abruptly or irreversibly.</p> <p>Risk is the product of the likelihood and impact of a damaging event. To better constrain the likelihood of climate tipping points, Lenton’s team developed and tested early warning methods [3.1]; work that was featured on the cover of <i>Nature Climate Change</i>. Applying these methods within a climate model revealed that a collapse of the Atlantic Meridional Overturning Circulation</p>		

(AMOC) carries robust early warning signals and identified which latitudes would be the most effective sites for an early warning system [3.2].

Lenton then co-edited a book, *Addressing Tipping Points for a Precarious Future* (London: British Academy (2013)), to start addressing these risks. Lenton and colleagues also worked with the European Environment Agency to identify the climate tipping points most relevant to Europe. This led to a project by the EU Joint Research Centre (Sevilla), with Lenton on the advisory board, which assessed the potential economic impacts of these tipping points. Lenton then collaborated with economists to include climate tipping points in the well-known Dynamic Integrated Climate-Economy (DICE) model. Their first joint study showed that the economic damages from an uncertain future tipping point have a greater influence on present day decisions than the deterministic climate damages in the standard model. This effect markedly increases the estimate of economic damage caused by emitting each extra tonne of carbon, known as the 'social cost of carbon' [3.3]. A second influential study showed that including five interacting tipping points in DICE radically alters the model's optimal policy recommendation. Rather than stabilising warming at $\sim 3^{\circ}\text{C}$, the recommendation shifts to limiting warming to $\sim 1.5^{\circ}\text{C}$, with a corresponding >8 -fold increase in the social cost of carbon [3.4].

The same study [3.4] also examined tipping point interactions. It showed that if passing one tipping point increases the likelihood of tipping another, this further abruptly increases the social cost of carbon. This result inspired Lenton to assess the latest evidence for tipping point interactions, including how strongly they could feed back to amplify climate change. This was his key contribution to a study concluding that interacting climate tipping points could potentially cascade to cause a global tipping point, creating a 'Hothouse Earth' state [3.5]. Recently, Lenton and colleagues have synthesised the evidence that multiple climate tipping points may already be underway, with the potential for cascading interactions between them [3.6] (see Figure). This increased risk provides scientific support for declarations of a 'climate emergency' and should compel much more decisive policy action to limit global warming [3.6].



3. References to the research (indicative maximum of six references)

3.1. **Lenton, T.M.**, Early warning of climate tipping points. *Nature Climate Change* 1, 201-209 (2011). DOI: 10.1038/nclimate1143

3.2. **Boulton, C.A., Allison, L.C. & Lenton, T.M.**, Early warning signals of Atlantic Meridional Overturning Circulation collapse in a fully coupled climate model. *Nature Communications*, 5, 5752 (2014). DOI: 10.1038/ncomms6752

3.3. Lontzek, T.S., Cai, Y., Judd, K.L. & **Lenton, T.M.**, Stochastic integrated assessment of climate tipping points indicates the need for strict climate policy. *Nature Climate Change*, 5, 441-444 (2015). DOI: 10.1038/nclimate2570

3.4. Cai, Y., **Lenton, T.M.** & Lontzek, T.S., Risk of multiple interacting tipping points should encourage rapid CO₂ emission reduction. *Nature Climate Change*, 6, 520-525 (2016). DOI: 10.1038/nclimate2964

3.5. Steffen, W., Rockström, J., Richardson, K., **Lenton, T.M.**, et al., Trajectories of the Earth System in the Anthropocene. *PNAS*, 115, 8252-8259 (2018). DOI: 10.1073/pnas.1810141115

3.6. **Lenton, T.M.**, Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W. & Schellnhuber, H.J., Climate tipping points – too risky to bet against. *Nature*, 575, 592-595 (2019). DOI: 10.1038/d41586-019-03595-0

4. Details of the impact (indicative maximum 750 words)**Influence on public policy, nationally and internationally**

Exeter's research contributions have been used by governments and public bodies across the globe, and have formed a vital part of the evidence base for climate policies in Africa, Germany, Australia, Canada, the Netherlands, the United States and the UK, as outlined below.

4.1 Providing vital evidence underpinning goals to limit global warming to well below 2°C

Exeter's research has identified how the risks posed by climate tipping points increase with global warming, and has been extensively cited in policy responses to the 2015 Paris Agreement goal of limiting global warming "to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C", now ratified by 189 Parties to the UNFCCC.

Lenton was a contributing author to the 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report on 'Global Warming of 1.5°C' (SR1.5) [5.1a], commissioned in response to the Paris Agreement. The special report makes the case for 'Avoiding Regional Tipping Points by Achieving More Ambitious Global Temperature Goals', and repeatedly cites Exeter's work [3.4]. The 2019 IPCC 'Special Report on the Ocean and Cryosphere in a Changing Climate' (SROCC) [5.1b] cites Exeter's work [3.4, 3.5] on the irreversibility of tipping points and their potential to amplify climate change and concludes: "If carbon emissions decline, the risk of...abrupt changes are reduced" [5.1b]. These two IPCC reports have influenced global policy directly, and the SR1.5 report is widely used to underpin ambitious mitigation policies and net zero targets.

Research by Lenton and his team also underpins a wide range of policy documents internationally. These use climate tipping points to determine targets to mitigate greenhouse gas emissions. The World Bank's 'Next Generation Africa Climate Business Plan' [5.2a] warns that "a 2°C warming could activate important tipping elements, raising the temperature further", citing [3.5]. The UK Government's 'Net Zero – The UK's contribution to stopping global warming' [5.2b] notes that without action, "Risks of crossing irreversible tipping points within the climate system...would be high". The German 'coal exit commission' strategy for phasing out coal-fired power generation by 2038 [5.2c], recognises that "without a dramatic reduction in emissions, the Earth could even be propelled into a 'hot age'", citing [3.5]. Australia's 'Northern Territory Climate Change Response Towards 2050' [5.2d] cites [3.1, 3.5] to support the Paris Agreement target, and cites [3.5] in recognising that "Global greenhouse gas (GHG) emissions need to decline rapidly to net zero".

4.2 Providing an eight-fold increase in the estimate of the social cost of carbon

Lenton and colleagues' research to add climate tipping points to the DICE model [3.3, 3.4] increased its estimates of the social cost of carbon up to >8-fold. William Nordhaus won the Nobel Prize in Economic Sciences in 2018 for developing Integrated Assessment Models, the first generation of which was the DICE model, and Exeter's research [3.3] is cited in the presentation information [5.3]. This crucial finding has had widespread influence on policy. The United Nations Environment Programme (UNEP) 'Inquiry into the Design of a Sustainable Financial System' [5.4a] cites Exeter's work [3.3] in recognising that "irreversible climate events ... could individually cost 10% of global GDP over 50 years". The 2018 IPCC SR1.5 [5.1a] cites [3.4] and the 2019 IPCC SROCC [5.1b] cites [3.3, 3.4] in recognising that "including extremes and abrupt changes, such as AMOC weakening, ice sheet collapse ... leads to a several-fold increase in the cost of carbon emissions". The Inter-American Development Bank cites [3.4] to underline the "needed ambition" of emission reduction for climate stabilisation at a safe level [5.4b].

4.3 Informing adaptation advice to international governments on tipping point risks and early warning systems

Lenton and team's identification of climate tipping point risks and early warning systems for them [3.1, 3.2] has informed climate change adaptation advice to governments.

Lenton's work helped drive the "commitment to climate and environmental action" of the Environmental Commissioner of Ontario (2015-19) [5.5a]. This commitment led to "three climate and four energy reports ... delivered to the Ontario Legislature", including a 2018 report citing [3.5] in a section on 'Getting ready for what's coming' [5.5b]. In a subsequent report, the Council of Canadian Academies' Expert Panel on Climate Change Risks and Adaptation Potential [5.5c] recognises the risk of "a large-scale dieback of the boreal forest", and notes that the associated "release of carbon stocks" can "exacerbate climate change", citing [3.1]. The European

Environment Agency [5.6a] recognises that “potential tipping points in the climate system give rise to serious concerns”, citing [3.5]. The Netherlands’ Environmental Assessment Agency [5.6b] also recognises the risk of “onomkeerbare kantelpunten” (irreversible tipping points), citing [3.6].

The US Congress commissioned a 2013 report by the National Research Council focused entirely on ‘Abrupt Impacts of Climate Change: Anticipating Surprises’, for which Lenton was a reviewer [5.7a]. The report cites [3.1] and “recommends development of an abrupt climate change early warning system”. The report’s conclusion highlights the need “to be serious about the threat of tipping points so as to better anticipate and better prepare ourselves for the inevitable surprises”.

The UK’s Global Food Security programme invited Lenton to co-author a 2017 report on ‘Environmental tipping points and food system dynamics’ [5.7b], which cites [3.1, 3.3] and explores the impacts of an AMOC collapse on food security, stating: “Early warning to allow mitigation and/or adaptation is key to minimising the global disruption this might cause”. The 2019 IPCC SROCC [5.1b] agrees: “A specific adaptation action is a monitoring and early warning system using observation and prediction systems, which can help to respond in time to effects of an AMOC decline”. That report cites [3.2] to show that “the observation arrays that are in place may allow the development of such an early warning system”.

Influence on public understanding, learning and participation

Lenton and team’s research has also enhanced public understanding of climate tipping points.

4.4 Stimulating public interest and engagement; Informing awareness and understanding

Research by Lenton and his team formed the basis of a 6-episode television series on ‘The Tipping Points’, featuring Lenton (opening episode), which has aired in over 50 countries worldwide to an estimated 500 million viewers [5.8a]. Lenton and his tipping points research featured in BBC1’s ‘Climate Change: The Facts’, with 3.56 million viewers [5.8b].

‘Climate tipping points – too risky to bet against’ [3.6] (Altmetric attention score >9000), was covered by >150 news outlets [5.9a]. One article referring to [3.6] in Metro received 135.6 million shares [5.9b]. Coverage focused on how more than half of the climate tipping points identified a decade ago are now active, with evidence for cascading interactions between them. Lenton appeared on ITV News at Ten (3.7 million viewers) [5.8c], BBC Radio 4: World at One (3 million listeners) [5.8d], and Newsday on BBC World Service (~1.3 million weekly listeners) [5.8e]. The European Parliament voted to declare a climate emergency on the day after [3.6] was published, with *The Guardian* [5.9c] linking this vote directly to their coverage [5.9d] of [3.6]. Reflecting in December 2020, the *New York Times* stated that [3.5] and ‘Timothy Lenton’s overview of tipping points’ [3.6] ‘have galvanized the climate movement’ [5.9e]. Also Exeter’s climate tipping points research has been shared with the public through a Massive Open Online Course, ‘Tipping Points: Climate Change and Society’ (lead educator: Lenton), with >13,000 enrolments [5.10].

4.5 Contributing to a change in public perception and mood

‘Trajectories of the Earth System in the Anthropocene’ [3.5] was the 4th ranked article of 2018 on Altmetric [5.9f] (attention score 5694 in 2018, >7000 in Dec. 2020) with coverage in >350 news outlets [5.9g]. CarbonBrief ranked it the most impactful climate research paper of 2018 [5.9h]. Media coverage focused on the possibility that an irreversible cascade of tipping points could lead to a ‘Hothouse Earth’ state. Dr Gail Bradbrook cites “the Hothouse Earth paper” [3.5] in an influential video that helped motivate the Extinction Rebellion protest movement [5.11a]. ‘Hothouse state’ became a new buzz phrase mentioned in the UK parliament [5.12a], and in Germany ‘Heißzeit’, a term already linked to [3.5] [5.12b], was voted word of the year 2018 [5.12c]. Extinction Rebellion also shared a J. P. Morgan special report [5.11b] which cited [3.5] regarding the risk that interacting tipping elements could trigger “a domino-like cascade”. This mass awareness-raising has contributed to a shift in public perception, part of a popular movement which led to declarations of a climate emergency in the UK and the EU in 2019.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1. **IPCC Reports:** 5.1a IPCC Special Report on Global Warming of 1.5°C (2018): cites [3.4] in 3.5.5, Box 3.6, p. 265 and [3.3] in Cross-Chapter Box 5, p.151, <https://www.ipcc.ch/sr15/>; 5.1b IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019): cites [3.4] at

- 1.1, p.77 and Cross-Chapter Box 5, p.109, cites [3.5] at 1.1, p.78, cites [3.2] at 6.7.3, p.623, cites [3.3, 3.4] at 6.8.6, p.626, <https://www.ipcc.ch/srocc>.
- 5.2. **Policy documents:** 5.2a World Bank (2020) The Next Generation Africa Climate Business Plan: Ramping Up Development-Centered Climate Action; 5.2b 'Net Zero: The UK's contribution to stopping global warming' Committee on Climate Change, May 2019; 5.2c Commission on Growth, Structural Change and Employment, Final Report to the German Federal Government (31/1/19); 5.2d Northern Territory Climate Change Response Towards 2050.
- 5.3. **Nobel Prize acknowledgement:** 'Economic Growth, Technological Change, And Climate Change', Scientific Background on the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2018.
- 5.4. **Policy documents referring to social cost of carbon:** 5.4a UNEP Inquiry into the Design of a Sustainable Financial System (2015) The Coming Financial Climate; 5.4b Inter-American Development Bank – Climate Policies and Nationally Determined Contributions.
- 5.5. **Contribution to policy in Canada:** 5.5a Letter of testimony from former Environmental Commissioner of Ontario 2015-2019; 5.5b Climate Action in Ontario: What's Next? 2018 Greenhouse Gas Project Report; 5.5c Council of Canadian Academies Expert Panel on Climate Change Risks and Adaptation Potential (2019) Canada's Top Climate Change Risks.
- 5.6. **Policy documents referring to tipping point risks:** 5.6a EEA Report – Is Europe living within the limits of our planet?; 5.6b Balans van de Leefomgeving 2020, Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency) (Dutch language).
- 5.7. **Advice to governments on tipping points and early warning systems:** 5.7a National Research Council 'Abrupt Impacts of Climate Change: Anticipating Surprises' (3/12/13) The National Academies Press; 5.7b Environmental tipping points & food system dynamics: Main Report (2017). The Global Food Security programme, UK.
- 5.8. **Participation in television programmes, television news and radio news:** 5.8a The Tipping Points <https://www.thetippingpoints.com/> (estimated 500 million viewers); 5.8b BBC 1 Climate Change: The Facts (2.87million viewers overnight & 3.56 million consolidated viewers (overnight + iPlayer)); 5.8c ITV News at Ten (reach 3,766,000); 5.8d BBC Radio 4 The World at One (3 million listeners); 5.8e Newsday on BBC World Service (~1.3 million listeners weekly).
- 5.9. **Media coverage:** [3.6]: 5.9a >9000 attention score <https://www.altmetric.com/details/71296068>; 5.9b Metro (135.6M shares) <https://metro.co.uk/2019/11/28/earth-crossed-nine-climate-tipping-points-scientists-fear-apocalypse-nigh-11232396/>; 5.9c The Guardian (28/11/19) www.theguardian.com/world/2019/nov/28/eu-parliament-declares-climate-emergency; 5.9d The Guardian (27/11/19) <https://www.theguardian.com/environment/2019/nov/27/climate-emergency-world-may-have-crossed-tipping-points> [3.5 & 3.6]; 5.9e The New York Times (26/12/20) www.nytimes.com/2020/12/26/style/climate-change-deep-adaptation.html; [3.5]: 5.9f ranked #4 in 2018 <https://www.altmetric.com/top100/2018/>; 5.9g >7000 attention score in 2020 www.altmetric.com/details/46149236; 5.9h ranked #1 in 2018 CarbonBrief Analysis: 'The climate papers most featured in the media 2018' www.carbonbrief.org/analysis-climate-papers-most-featured-in-media-2018.
- 5.10. **MOOC:** www.futurelearn.com/courses/tipping-points-climate-change-and-society with 13,795 enrolments [December 2020].
- 5.11. **Extinction Rebellion:** 5.11a (Gail Bradbrook) 'Heading for Extinction and What to do About it' www.youtube.com/watch?v=b2Vkc4SnwY0 (from 7:05 onwards); 5.11b Extinction Rebellion share Mackie, D. and Murray, J. 'Risky business: the climate and the macroeconomy' J.P. Morgan (14/1/20), which cites [3.5], p.8, <https://tinyurl.com/5mvwtafd>.
- 5.12. **'Hothouse state' buzz phrase:** 5.12a In 'The Climate Emergency' debate in the House of Commons (17/10/19), MP for Lewisham, Deptford (Lab) stated "Melting icecaps, warming seas and deforestation could trigger a 'hothouse' state"; 5.12b Sueddeutsche Zeitung cites [3.5] (German language); 5.12c Society for the German Language, 'Heißzeit' voted word of the year 2018 <https://qfds.de/wort-des-jahres-2018/> (German / English language).