



Pathways for prevention of cascading tipping points



Strong governance, accelerated action, and empowered communities are essential to avoid cascading Earth system tipping points and achieve lasting, transformative change.

Climate change tipping points—thresholds beyond which small changes can cascade into large, irreversible transformations—have been identified for ice sheets, rainforests and ocean currents. The potential for such transitions varies in likelihood and impact, depending on the affected sector of the climate system, and transitions in different sectors could occur simultaneously¹. Tipping points are not isolated events. The collapse of one system can amplify risks in others, setting off domino effects across continents and oceans. Yet, Earth system models continue to disagree on how these elements behave and interact. Model discrepancies create uncertainty about global tipping point risks. The interdependencies between tipping points, their potential for irreversible amplification and feedback, and strategies for managing and coping with uncertainties were the topics of two meetings in Exeter, UK in early July: the Global Tipping Points Conference (global-tipping-points.org) and the Exeter Climate Conference (exeterclimateforum.com).

Amid growing concerns about tipping point risks and model uncertainties, discussions at the two meetings also included proposals aimed at altering the climate system through the controversial approach of geoengineering.

Geoengineering for climate intervention

Defined as the deliberate, large-scale manipulation of the planetary environment to counteract anthropogenic climate change, geoengineering has long faced criticism. It is sometimes seen as an easy technological fix that delays or replaces necessary systemic changes and reduces the pressure to decarbonize. We currently have a limited understanding of its potential impacts and feedback on the Earth system, which could lead to unpredictable side effects. Global

governance is another obstacle; geoengineering actions potentially affect the entire planet, but it is unclear who will decide when and how to use them.

One approach, marine carbon dioxide removal based on the manipulation of seawater carbonate chemistry, is promising according to Paul Halloran (University of Exeter, UK)² and is currently being tested at the SeaCURE pilot plant in Weymouth, UK. The seawater entering the plant is acidified to facilitate the rapid removal of over 90% of dissolved carbon dioxide, which is then used for other applications or stored. The decarbonized water is then basified (an increase in pH) and released to the surface ocean, where the natural exchange of carbon dioxide between the ocean and atmosphere can take place, allowing for more carbon uptake. However, released water with low carbon could disrupt chemical equilibria, impact nutrient cycling and microbial communities, and potentially harm marine ecosystems such as phytoplankton. Also, large-scale deployment remains incompatible with current environmental standards and regulations.

Solar radiation management involves intentionally altering the Earth's radiative balance to reflect more sunlight and cool the planet. Techniques such as marine cloud brightening, where fine particles are sprayed into the atmosphere over the oceans to make the clouds brighter, and stratospheric aerosol injection, where aerosols are injected into the stratosphere to increase the albedo, fall under this category. However, these climate interventions pose serious risks, as explained by Jim Haywood (University of Exeter, UK). Marine cloud brightening could change atmospheric circulation and enhance the ozone production in the tropical upper troposphere and lower stratosphere³. Stratospheric aerosol injection could lead to tropospheric overcooling in the tropics and residual warming in the polar regions, with substantial changes to stratospheric temperatures, water vapor and circulation⁴.

Methane removal technologies include the addition of chlorine to the atmosphere to accelerate the breakdown of methane and reduce its concentration more rapidly⁵. However, the artificial increase in reactive chlorine emissions requires more energy than the capture of carbon dioxide, according to Fiona O'Connor

(University of Exeter, UK). It also poses significant risks, such as damaging the ozone layer and producing toxic byproducts that degrade air quality.

All speakers agreed that the reduction of carbon emissions remains safer, more cost-effective, and more reliable than attempting to mitigate global warming through geoengineering. Nonetheless, critical questions remain and, as Stephen Gardiner (University of Washington, US) emphasized, incorporating ethical considerations into climate geoengineering discussions is essential. We must determine under what circumstances—if any—geoengineering interventions could be justified and carefully consider at which point such approaches carry greater risks than the future climate scenarios they aim to prevent.

Tipped for the better

Much attention has focused on the risks of crossing dangerous thresholds and on potential interventions to mitigate climate change. Yet, tipping points may also hold the key to catalyzing rapid, positive change.

Tipping points do not need to be negative. Tipping points can also describe positive transition thresholds in social, technological, economic, or ecological systems that, once crossed, trigger rapid, self-reinforcing shifts toward more sustainable and desirable outcomes. Timothy Lenton (University of Exeter, UK) emphasized the importance of amplifying these positive tipping points to reduce the risks of Earth system tipping points and accelerate transformative climate action.

Examples of positive tipping points are already emerging in the energy and transport sectors. Jean-François Mercure (University of Exeter, UK) highlighted how the widespread adoption of solar and wind energy in the past few years has made renewables the fastest-growing part of the energy system. A global solar energy tipping point could be reached in the coming years, where solar power will gradually dominate global electricity markets, without any new climate policies⁶. Similarly, electric vehicles have seen rapid innovation, significant cost reductions, and growing popularity over the past years. Their sales are now rising at an average rate of 40% per

year in Europe. Arguably, European Union markets could reach a tipping point, which could spread globally. Simon Sharpe (University College London, UK) explained how small, well-targeted interventions, such as the deployment of subsidies to produce clean materials such as steel, could accelerate and further strengthen the transition to cleaner technologies in the energy sector.

Emotions as barriers for climate action

People's emotions and desires for the future are crucial in enabling the transition to a more sustainable world. Yet, some psychological and emotional barriers must be overcome to trigger positive tipping points and accelerate climate action.

John Rowlett (De Montfort University, UK) noted that negative social tipping points significantly affect choices around energy efficiency and solar panel adoption. Using the UK as an example, Rowlett explained that although the government offers subsidies for home solar panel installation, many older people do not take advantage of them due to a lack of awareness about the environmental benefits and the potential improvements to their lives. Increased engagement with such communities is essential and could be achieved through targeted marketing campaigns that take into account people's perceptions.

Climate change can generate fear, outrage and hope, and some of these emotions can be detrimental to climate action, according to Genevieve Guenther (End Climate Silence; <https://www.endclimatesilence.org/>). While some people are

motivated by fear, many feel overwhelmed by the challenges ahead and ultimately slip into despair. Guenther argued that hope can be a more powerful force for mobilization. She advocated shifting our emotional response to climate change—from fear and outrage to desire—to transform hope into collective action or, at the very least, into a unified global commitment to act. We need to adapt the way climate science is communicated by finding new, inclusive ways to talk about the climate crisis⁷.

Ways forward to action

Strong, forward-looking governance is essential. We must transform energy, transportation, food, and economic systems together. We also need tailored, just, and community-based solutions that minimize potential negative social tipping points. A global constitution (<https://Globalconstitution.org>), as proposed by Joyeeta Gupta (University of Amsterdam, Netherlands), could serve as a foundation for transformative climate justice and more inclusive, bottom-up representation. The idea is to develop a shared set of principles, rights and responsibilities to help address the world's most pressing environmental and social issues.

Systemic and structural changes require collective action. Ultimately, people hold the power to drive change, and building their resilience and empowerment is essential to unleashing effective and lasting climate action.

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