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Discussion Paper

Complexity as a Catalyst: Enabling Global Environmental Change in a Deeply Divided World

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ISBN: 978-92-808-6662-9 © United Nations University 2025.

Citation: Simon Sharpe and Adam Day, "Complexity as a Catalyst: Adaptive Global Governance in a Deeply Divided World", GGI Platform Discussion Paper (New York, United Nations University, 2025).

Introduction

Meeting internationally agreed climate change goals requires dramatically faster progress on reducing global emissions as well as transformative adaptation across sectors. However, many current climate change policy, diplomacy and governance structures are implicitly based on ideas of an economy in equilibrium, where decarbonization is costly, diplomacy is a negative-sum game and national interests are fixed. This is neither reflective of reality nor helpful for the rapid change that must be achieved. It demands cooperation in the most difficult way possible, in a world that is more deeply divided and contested than ever. In this context, concepts from complexity science offer a different way of thinking about the challenge of transitioning to net zero. Rather than demanding global cooperation from the outset, complexity suggests that change can be driven by enabling better feedback loops, giving rise to adaptive governance systems that react to and incentivize a shift away from fossil fuels. In this discussion paper we offer a broad sense of how complexity thinking could transform how we think of global environmental governance in a deeply divided world.

Understanding complex systems

At its core, complexity thinking is a framework for understanding systems as dynamic, interconnected and unpredictable. Unlike linear thinking – where cause and effect are clear and manageable – complexity recognizes that in many systems small actions can have large effects, patterns emerge from interactions among parts, and outcomes cannot be precisely predicted. Scholarship on complexity has investigated a wide range of global challenges, including financial markets, sociopolitical processes, the environment and cyberspace.[1]

Several key characteristics define complex systems:

- **Feedback loops:** Reinforcing feedback (amplifying change) and balancing feedback (stabilizing change) continuously reshape a system. For example, melting ice reduces light reflection, causing more warming (a reinforcing feedback); over the long term, higher carbon concentrations in the atmosphere increase carbon absorption and sequestration in natural systems, leading temperatures to fall (a balancing feedback).
- **Non-linearity:** Inputs do not lead to proportional outputs, meaning that change can be sudden and occur far from its proximate cause. For example, an incremental global temperature rise could result in large-scale coral bleaching and sea-level rise. A toxic spill in one part of the world can cause the collapse of biodiversity tens of thousands of miles away.
- **Emergence:** The behaviour of the whole system cannot be understood merely by analysing its parts. Urban heat islands, rising sea levels and desertification all emerge from many interacting variables around the world. Deforestation is more than just a loss of trees, it can transform a rainforest into a savannah, disrupting global carbon cycles.
- **Adaptation:** Systems evolve and adapt together with the actors trying to govern them. Rather than think of the environment as the object of global governance, complexity thinking demands that we consider social, environmental, financial

[1] Andreas Duit and Victor Galaz, "Governance and Complexity – Emerging Issues for Governance Theory", *Governance*, vol. 21, No. 3 (2008), pp. 311–335; Simon Levin et al., "The Governance of Global Commons", *Ecological Economics*, vol. 70, No. 5 (2011), pp. 940–949; Oran R. Young, *Governing Complex Systems: Social Capital for the Anthropocene* (Cambridge, Massachusetts, MIT Press, 2017); Adam Day, *The Forever Crisis* (London, Routledge, 2025).

and governance actors together as a single interconnected system. Governance is not about adapting to a new reality; it is about adapting within it.

Complexity thinking emphasizes dynamism and uncertainty – reflecting the reality that systems are constantly in a state of flux. They cannot be optimized, controlled or simplified. The challenge instead is to find ways to guide the system so it self-organizes differently and evolves in a desired direction. This can be done by rewriting the underlying rules of the system that determine its patterns of behaviour. Problems in complex systems are rarely 'solved'. Instead, they require ongoing, adaptive engagement, with policy and governance continuously evolving to fit the challenge.[2]

Implications for climate change risk assessment and adaptation

Climate science and Earth systems science have evolved over recent decades to more fully incorporate a complex systems understanding. There is increasing knowledge of the many feedback loops that can accelerate climate change (and in some cases limit its pace), the interactions between feedbacks across different elements of the Earth system (oceans, land, atmosphere, cryosphere and ecosystems), and tipping points where a small change in an underlying variable can lead to a large and non-linear change in the state of the system.[3]

To enable adaptation of governance processes at the national level, an important implication is the need to focus on thresholds of non-linear impact.[4] For example, the risk of crop failure due to a temperature tolerance threshold being passed may be more important than a central projection of loss of yield in a typical year. There is also a need to consider cascading risks: the potential for disruption to spread from one system to another. Examples include the interdependence of energy, transport, water and health systems within a city, or the links between extreme weather events, crop failure, international trade, food prices and social stability.[5] As we become more interconnected and interdependent, small changes in one part of the system can drive far greater problems. Consider the enormous impacts of a ship blocking the Suez Canal, the global price impact of the war in Ukraine or the price spikes in coffee and chocolate after crop failures in West Africa.

While adaptation is often a local challenge, some climate risks – such as disruption of global food markets, or the effect of changing temperatures on the spread of infectious diseases – have strong cross-border elements. These risks are emergent effects arising from the interactions between countries, as well as between human and natural systems; they cannot be controlled by any one country alone. The implication for global governance is that these risks should be systematically identified and managed through dedicated institutions that are not siloed in a single domain.

A useful starting point could be to establish a process to regularly produce an environmental risk assessment for heads of government. Drawing on a wide range of science across environmental domains (climate, biodiversity, pollution, etc.), this would identify the largest risks, giving a clear picture of the severity of the threat and highlighting areas where action is likely to be

[2] See, V. Galaz, ed., *Global Challenges, Governance, and Complexity Applications and Frontiers* (Edward Elgar, 2019); A. Orsini and P. Le Prestre, "Complex Systems and International Governance", *International Studies Review* (2019).

[3] T. M. Lenton et al., *The Global Tipping Points Report 2023* (University of Exeter, 2023). Available at https://global-tipping-points.org/.

[4] S. Sharpe, "Telling the boiling frog what he needs to know: why climate change risks should be plotted as probability over time", *Geoscience Communication*, vol. 2, No. 1 (2019). Available at https://gc.copernicus.org/articles/2/95/2019/.

[5] D. Quiggin, et al. *Climate change risk assessment 2021* (London, Chatham House, 2019). Available at https://www.chathamhouse.org/2021/09/climate-change-risk-assessment-2021/04-cascading-systemic-risks.

needed for effective risk management. Compared to climate science assessments such as those produced by the Intergovernmental Panel on Climate Change, the risk assessment for heads of government would be shorter, annual and focused on the largest risks and plausible worst-case outcomes, following the principles outlined by the Scientific Advisory Board of the United Nations Secretary-General in 2016.[6]

Implications for national policy on the transition to zero emission systems

The United Nations Framework Convention on Climate Change has as its ultimate objective the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".[7] Concentrations of greenhouse gases can only be stabilized when net global anthropogenic emissions fall to zero.

Early work on the economics of emissions reduction often described the challenge in linear terms of 'marginal abatement' and assumed that the more emissions were to be reduced, the more this would cost. The challenge is now increasingly understood in terms of system transitions – moves to new zero emission technologies and their accompanying physical, social and financial infrastructure.[8] Recent research suggests that at a global level, the effect of these system transitions could be a large net saving over the coming decades due to the rapidly falling costs of clean energy technologies.[9]

Reinforcing feedback loops are central to the processes of technological and sociopolitical change that drive system transitions forward. These include learning by doing (the more something is made, the better it gets), economies of scale (the more something is made, the cheaper it gets), network effects (the more people use something, the more useful it becomes to others), and the reinforcing feedbacks between investment, innovation, cost reduction and demand for new technologies. These effects drive non-linear change, such as the fall by a factor of 10,000 in the cost of solar photovoltaics over the past decade, or the rise in electric vehicles' share of global car sales, from 2.6 per cent in 2019 to over 20 per cent in 2024.[10]

These reinforcing feedbacks have important implications for policy. Early in a transition, policies that directly support the development and deployment of new technologies (such as targeted subsidies or clean technology mandates) can benefit from a self-amplifying effect. But they can also be obstructed by high barriers to widespread use, technological hurdles and both economic and psychological path dependencies. Early in a transition, policies that put pressure on the incumbent technology system, such as carbon pricing, are likely to push it to operate more efficiently in its current state, and unlikely to benefit from any self-amplifying effect (though

6 Advisory Board of the United Nations Secretary-General, "Assessing the risks of climate change", Policy Brief (United Nations publication, 2016). Available at https://unesdoc.unesco.org/ark:/48223/pf0000246477.

7 *United Nations Framework Convention on Climate Change* (United Nations publication, 1992). Available at https://unfccc.int/process-and-meetings/the-convention/history-of-the-convention/convention-documents. Please note: Stabilization of greenhouse gas concentrations in the atmosphere can only be achieved when net anthropogenic emissions fall to zero.

8 Intergovernmental Panel on Climate Change (IPCC), *Special Report: Global Warming of 1.5 °C* (2018).

9 R. Way, et al., "Empirically grounded technology forecasts and the energy transition", *Joule,* vol. 6, No. 9 (2022). Available at https://www.sciencedirect.com/science/article/pii/S254243512200410X.

10 International Energy Agency, *Global EV Outlook 2025* (Paris, 2025) Available at https://www.iea.org/reports/global-ev-outlook-2025; International Energy Agency, *Global EV Outlook 2020* (Paris, 2020). Available at: https://www.iea.org/reports/global-ev-outlook-2020.

they may still be helpful in reducing emissions).[11] Similarly, policies that attempt to limit the supply of fossil fuels are likely to face the strongest possible opposition from a powerful incumbent industry (a balancing feedback likely to maintain a system in its current state). In contrast, policies that dramatically reduce demand for fossil fuels by developing and deploying cost-effective zero emission systems are likely to benefit from self-amplifying feedbacks that drive rapid progress. Complexity thinking offers the concept of "strong attractors" – states that exert a strong gravitational pull that helps to organize and stabilize a given system. The goal of any net zero policy should be to shift the strong attractors away from fossil fuels.

The non-linearity of cause and effect in the economy means that it can be useful for policy to target tipping points in transitions – points where investor expectations, business strategies and consumer preferences shift decisively from old technologies to new.[12] While these are not always easy to predict, thresholds of cost or profitability can serve as proxies: governments can design taxes, subsidies or regulations to make clean technologies cheaper for consumers or more profitable for businesses than fossil fuels, in a given sector. This contrasts with the logic of 'internalizing the externality', where a carbon price is set to reflect the 'social cost of carbon' – an inherently subjective value which bears no relationship to the dynamics of the structural change that is necessary for the transition.

Implications for climate change diplomacy

The complex systems understanding of the economy has strong implications for climate change diplomacy. Put simply: if we adopt a systemic lens that allows for a wider range of non-linear effects, the enormous benefits of getting to net zero are far more apparent and measurable. It enables a calculation showing that the transition to zero carbon systems involves a net saving rather than a net cost. Instead of the negative-sum game of dividing up the global carbon budget and sharing the burden of the cost, climate change diplomacy can become a positive-sum game where even highly competitive actors are incentivized to drive forward the transition.

A key insight from complexity thinking is that even deeply opposed, competitive actors can be incentivized to act in a way that enables systems change. We don't necessarily need all the major emitters to agree on a common emissions reduction plan or to cooperate across the board. By identifying key threshold points where systems can tip into new "phase spaces", where the organizing rules and patterns favour renewable forms of energy, even the most bitterly opposed actors can find common benefit in investing in the transition away from fossil fuels. But complexity thinking can also help us understand where coordinated action is most useful – and where the highest leverage can be found.

11 J. Lilliestam, A. Patt and G. Bersalli, "On the quality of emissions reductions: observed effects of carbon pricing on investments, innovation, and operational shifts. A response to van den Bergh and Savin (2021)", *Environmental & Resource Economics*, vol. 83, No. 3 (2022): 733–758. Available at https://ideas.repec.org/a/kap/enreec/v83y2022i3d10.1007_s10640-022-00708-8.html.

12 S. Sharpe and T. M. Lenton, "Upward-scaling tipping cascades to meet climate goals: plausible grounds for hope", *Climate Policy,* vol. 21, No. 4 (2021). Available at https://www.tandfonline.com/doi/abs/10.1080/14693062.2020.1870097.

The property of emergence – the behaviour of a system being different from the behaviour of its constituent parts – is essential to understand the potential for more effective climate change diplomacy. Countries together produce change in the global economy, and this change shapes countries' options and future actions. There are many opportunities to achieve coordination gains, so that transitions become faster, easier and less costly (or achieve greater economic benefit). Some of these can arise from cooperation, such as joint research and development to drive faster innovation, coordinated deployment policies enlarging economies of scale and driving faster cost reduction, harmonized standards enabling infrastructure interoperability, and trade agreements establishing level playing fields where they are needed. For the past three years, the International Energy Agency and the United Nations Climate Change High-Level Champions have assessed these opportunities to be far from fully exploited.[13]

The focus of climate change diplomacy on Nationally Determined Contributions (NDCs) – unilateral actions – radically underappreciates the extent to which countries' options and actions are dependent on each other. The moves towards clean power that are central to most countries' NDCs are only possible because of the combined effect of early development of solar PV technology, led by the United States and Japan, early deployment of solar power, led by Germany, and the massive scaling up of production (with consequent cost declines), led by China.[14] Ending deforestation is likely to be possible only through collaborative action between countries that are the major producers and consumers of agricultural commodities. The difficulty of decarbonizing energy intensive industries depends overwhelmingly on conditions in global markets. If countries only act unilaterally instead of working together to change the systems they are part of, the transition will be more difficult than it needs to be – at enormous cost to all.[15]

The reinforcing feedbacks of clean technology development and diffusion play out internationally, and tipping points in the transition can be global as well as national. In most of the major greenhouse gas-emitting sectors of the economy, around ten countries jointly account for three-quarters of global consumption or production.[16] This suggests that plurilateral cooperation – small groups of countries working together – could change economic conditions in a way that makes it easier for all other countries to make the transition in each sector.

The concept of adaptation shows that even governments in competition can be driven to adopt common environmental policies and approaches. As systems change, countries' interests evolve, and agents adapt to new realities in their surroundings. Governments that once resisted renewable power, for example, increasingly find that deploying it advances their goals in energy security, productivity and resilience. This dynamic opens the door to progressively stronger forms of cooperation: beginning with sharing knowledge, moving toward aligned policies and eventually establishing shared rules to govern sectors. Cooperation, therefore, should not be dismissed as impossible simply because competition exists; every trade agreement demonstrates that collaboration can occur within a context of rivalry. Substantial cooperation will always be difficult where strong interests are involved, but by recognizing adaptation as a driver of shifting national interests, diplomacy can unlock pathways to deeper coordination. Legally binding agreements, in this view, are the culmination of an adaptive process, not its starting point.

[13] International Energy Agency, International Renewable Energy Agency and United Nations Climate Change High-Level Champions, *The Breakthrough Agenda Report 2022* (2022). Available at https://www.iea.org/reports/breakthrough-agenda-report-2022; International Energy Agency, International Renewable Energy Agency and United Nations Climate Change High-Level Champions, *The Breakthrough Agenda Report 2023* (2023). Available at https://www.iea.org/reports/breakthrough-agenda-report-2023; International Energy Agency and United Nations Climate Change High-Level Champions, *The Breakthrough Agenda Report 2024* (2024). Available at https://www.iea.org/reports/breakthrough-agenda-report-2024.

[14] G. F. Nemet, *How solar energy became cheap: a model for low carbon innovation* (Routledge, 2019)

[15] International Energy Agency, *Net Zero by 2050* (Paris, 2021). Available at https://www.iea.org/reports/net-zero-by-2050.

[16] M. Meldrum, et al., *The Breakthrough Effect: How to Trigger a Cascade of Tipping Points to Accelerate the Net Zero Transition* (Systemiq, 2023). Available at https://www.systemiq.earth/breakthrough-effect/.

Implications for the institutions of global climate change governance

The process of negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) is important and valuable for agreeing global goals, and for norm-setting in relation to countries' individual national actions. It has generated agreed global goals on emissions (the balance of sources and sinks), temperature change and financial assistance, and has helped to establish the norm of national net zero targets.

Countries do not attempt to use the UNFCCC process to negotiate practical cooperation on low carbon transitions or adaptation and resilience, targeting coordination gains of the kind described above. The reason is not because the process has been hijacked by fossil fuel interests; it is because there is always a trade-off in diplomacy between breadth and depth and it is impossible to negotiate matters of substance by seeking consensus among a group of 196 countries.

The coordination gains that could accelerate emissions reductions are most likely to be accessed through focused diplomacy in each of the main greenhouse gas-emitting sectors – power, road transport, shipping, aviation, buildings, steel, cement, chemicals and agriculture. Each of these sectors has its own distinct political economy, industrial and financial structures, influential countries and technological options. It is within the roughly defined boundary of each sector that problems must be solved to allow transitions to zero emission systems.[17] Few, if any, of these sectors benefit from institutions created for the purpose of enabling the transition, with a focus on practical cooperation and the participation of relevant policymakers across a critical mass of countries (enough to move global markets but not so many that substantial agreement becomes impossible).

While the many government, civil society and business-led initiatives for practical cooperation that do exist are important foundations, they are no substitute for serious intergovernmental diplomacy supported by dedicated institutions. The United Nations Climate Change Council proposed by President Lula of Brazil could play an instrumental role in bringing this new ecosystem of practical action-focused diplomacy into being. The Council could serve as a forum for strategic discussion among countries regarding the most significant challenges faced in low carbon transitions and adaptation, identifying where international cooperation is most needed, and giving a mandate and legitimacy to the institutions best placed to facilitate it, whether they are already existing or newly created.

Complexity is often associated with holistic thinking, for good reason: all elements of a complex system are influenced by each other. But effective action requires holism with focus. When governments gather and discuss emissions reduction across the whole economy, it is rarely possible to agree anything specific. The scope is too broad. Similarly, attempting to create some linkage between the UNFCCC and the Convention on Biological Diversity will achieve little if processes for effective, practical international cooperation within either of those fields are yet to be established.

[17] D. G. Victor, F. W. Geels and S. Sharpe, *Accelerating the low carbon transition: the case for stronger, more targeted and coordinated international action* (Energy Transitions Commission, 2019). Available at https://www.energy-transitions.org/publications/accelerating-the-low-carbon-transition/.

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