The "Climate Change Paradigm" at a Crossroads

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IinteR-La+B, International Interdisciplinary Research Laboratory, Milan, Società Svizzera, Tuesday 9 September 2025

1. Introduction

In the past few decades, climate change has triggered a global science-based, policy-driven process of structural transformation that offers an alternative paradigm to the techno-economic and social systems still dominated by the «fossil energy paradigm». Although the implementation of the climate agenda is still far from the main objectives of the Paris Agreement, this induced transformation is challenged by international changes and internal constraints that slow its progress.

In this position paper we highlight, for discussion, some of the processes that may challenge, slow down and weaken the «climate change paradigm» in this phase. We take a socio-economic and policy perspective, but we aim at raising multidisciplinary awareness towards better climate transition policies, improved collective choices, and stronger alliances among actors in the science system, in the economy, and in policy making. Although the «position» of the paper is clear, it does not propose conclusions. We start from highlighting the deep differences between the «fossil energy paradigm» and the «climate change paradigm», then proceed with our selection of two dynamics of innovation and structural change and three geopolitical issues that can create uncertainties for the transition to the «climate change paradigm».

2. Clash between paradigms

In a political economy perspective, climate change, and the Net Zero global strategy can be better understood by referring to two clashing paradigms: the «fossils paradigm» and the «climate change paradigm». They represent divergent paths for the present and future, each seeking to gain dominance in the world economy, society, politics, and the ethos of this age.

The «fossil energy regime» has established its dominance since the Industrial Revolution. There is no global shortage of fossil resources – gas, coal, and oil – which still cover 81% of global primary energy consumption, with reserves-to-consumption ratios that cover more years today than forty years ago (Diaz Lopez et al. 2023). The issue is mainly geopolitical. The game of «fossil superpowers» (US, Russia, and OPEC+) is to alternate over-supply and supply restrictions with geopolitical strategies aimed at leveraging their control over resources to influence the international system. Conflicts in key geopolitical hubs can boost energy prices and rents whereas strategies of low-price fossil materials can weaken the clean energy and Net Zero transition.

Climate change has generated an alternative transformative paradigm for the world system starting from climate science with the vision of climate as a critical «global commons» for the destiny of humankind. Climate change policy and governance have been triggered by climate science, starting with the creation of the IPCC (Intergovernmental Panel on Climate Change) at the end of the 1980s (IPCC 2023). In the «fossils paradigm», the key actors are the nations, the energy industry, the markets, and the private stakeholder linked to fossil energy profitability that leverage the material power of energy as a «private good». Instead, within the «climate change paradigm», the central role is taken by the international community, policy makers, science, and cooperation. This paradigm relies heavily on science-based policies rather than markets as the primary trigger for a techno-economic transition and structural change.

The climate paradigm can be read in light of a changing approach toward global commons. Climate can be subject to the «Tragedy of the Commons» proposed by Garrett Hardin (Hardin 1968), in which the resource is «open access» and the user operates within a «prisoner's

dilemma» that can lead to the destruction of the same resource where individual incentives are against the collective interest, resulting in a failure of cooperation. On the other hand, the global policies for climate change represent Elinor Ostrom's approach of «governing the commons» through rules, duties, and rights, with the fundamental role of the «community» in which individuals cooperate giving rise to sustainable self-government (Ostrom 1990).
Governing climate at the global level means shifting from the «tragedy of the commons» to «governing the commons» as in Ostrom's vision, with a central role for the «international community» and sovereign states giving up part of their national sovereignty for the benefits of cooperation (Krasner 1983; Zoboli 2010). The outcome of the two regimes will not be neutral and can create global winners and losers in terms of power, wealth distribution, global well-being, and inequality. The two regimes inevitably clash, creating a stark, opposing tension. Despite limited successes in international climate governance, similar global frameworks are largely absent from other global issues such as peace, security, health, or global poverty. Nowadays, international relations are increasingly fragmented and power-driven, yet climate governance offers a space for cooperation to protect vital ecosystems and potentially promote peace and global solidarity.

3.1 Innovation and structural change: Paths of «clean tech» and Net Zero companies

The development of the «climate change paradigm» boosted processes of green industrial innovation and economic structural change which have a critical role for the credibility of the new paradigm as a socio-economic alternative. Some examples of the success of climate policies in shaping the global technology structure boosting innovation are:

i) the increase in the share of renewable sources (RES) in the global energy system has grown significantly with wind and solar expanding from near zero to exponential trends (in EU27 RES accounted for 24% of total energy consumption, and up to 44% of electricity consumption);

ii) the global deployment of green technologies has increased thanks also to global policy incentives such as electric vehicles (EVs: 40 million units), and other «radical» climate-energy innovations have emerged (e.g., hydrogen-based technologies; carbon capture utilization storage;

nuclear fusion), attracting substantial interest and investments (D'Amato et al. 2024).

In the EU the picture is dynamic but uneven, with strong EU leadership in some sectors (e.g., wind) but incomplete value chains in others (e.g., photovoltaics). The latter remain highly exposed to import penetration from China, which has emerged as the global giant of clean-tech industries (D'Amato et al. 2024). China is the actor benefitting from these imbalances, but it is also a possible ally of the EU in the global clean tech movement after the US administration is abandoning these industrial trajectories in favour of fossil resources.
Climate policies have significantly reshaped the strategies of the private sector toward more sustainable approaches in doing business, particularly among multinational companies and the banking sector, driving a growing commitment to Net Zero.
But investment needs for transitions remain an important issue either for the private sector or for governments. These huge investment needs require massive public funding, but even more so, they depend on the profit-motivated private sector's developing a massive propensity to invest, on the order of two to five times as much as governments (Cerniglia and Saraceno, 2025).

3.2 Innovation and structural change: Digital/AI revolution: climate friend or foe?

The digital/AI revolution is deeply changing economic and social systems. It is expected to generate huge gains of efficiency and productivity together with uncertain intersections with the climate change paradigm. The overall impact remains highly uncertain due to the pros and cons of AI on energy and climate (Crawford 2024; Luers et al. 2024). On one hand AI-related electricity consumption is expected to grow by as much as 50% annually from 2023 to 2030, principally due to the increasing computational power needed by new generative AI models requiring higher complexity, longer training, and more extensive data processing compared to traditional AI systems (Ephoc 2025). On the other hand, energy gains may derive from the use of renewable energy sources for powering data centres or from advanced cooling techniques. Moreover, AI might play a significant role in optimizing energy consumption and supporting decarbonization efforts across various sectors (e.g., by creating smarter grids, enabling efficiency and reducing waste in the industrial sector, improving logistics and fleet management, reducing energy consumption and emissions by analysing traffic, fuel, and route data) (World Economic Forum 2025).

The general issue is that the digital/AI transition is ontologically different from the climate energy transition, even though they are often considered together as «twin transitions» (Zoboli 2024). While the climate-energy transition originates from exogenous impulses of observational sciences driving large global public policies of a problem-solving nature, the digital revolution has always had a strong endogeneity driven by the private sector and the economic and power system. Essentially, while the climate-energy transition is dominated by «collective choices» for the common good, the digital one is driven by the pursuit of private profits and national power, and it is not guided ex-ante by grand goals for humanity, except those identified ex post with the emergence of its infinite applications. It is therefore awaiting social governance. Moreover, the collapse of computing costs changed the input mix of the economic system in which information and knowledge take importance over capital and labour, raising concern on the potential social effects and requiring us to rethink a complete reconfiguration of the «social contract» on production and distribution of income that underpins the capitalism system (Nordhaus 2021).

Unlike the climate-energy transition, which is «closed-ended» with Net Zero convergence, the digital/AI transition is «open-ended» and potentially infinite. The digital transition is flexible, cumulative, and innovation-driven, with large economic returns; AI is able to transform reality beyond control or social governance, creating its own demand with unpredictable and potentially anarchic socio-economic effects.

4.1 Geopolitical issues: Appropriation of the «Global carbon budget»

The Intergovernmental Panel on Climate Change (IPCC) led to the definition of the Global Carbon Budget (GCB), understood as the cumulative amount of allowable carbon emissions to meet a global temperature target, which can be conceptualised as a non-renewable resource to be allocated across generations in a «socially optimal» way (Barbier and Burgess 2017). But the reality is more complex than this. Global climate governance is a game of cooperation and conflicts, both between Global North and Global South and inside the same two

groups. Fairness and global equity are crucial for the transition towards the «climate change paradigm» (Williges et al. 2022).
In this framework, innovation in sustainable and green technologies can play a critical role in «expanding» the GCB (Quadrio Curzio and Zoboli 2020). Although clean energy innovation is largely concentrated in the Global North and China, it indirectly benefits the Global South by enlarging the residual GCB through innovation-led emission reductions (Williges et al. 2022). The global impact of green innovation would be maximised if energy-climate innovation is transferred to the Global South on fair terms, but major Global North countries have embraced Net Zero also as a strategy for securing first-mover advantages in global technological leadership, with the Global South expected to be a major buyer of such technologies (Mazzanti and Zoboli 2010; D'Amato et al. 2024). The negotiations on «Loss and damages» within the Conference of the Part (COPs) and further developments of «Global climate finance» can positively contribute but cannot solve the issue at the appropriate scale (UNFCCC, 2025a, UNFCCC, 2025b).
The US leadership of the fossil paradigm may limit the role of innovation in expanding the residual GCB while simultaneously reinforcing the appropriation of GCB by major emitters. On the opposite side, China and the EU are positioning themselves as new potential allies of the Global South, pursuing ambitious energy-transition strategies and global clean-tech leadership. The new geopolitical equilibrium is between incumbent major «fossil superpowers» and new green emerging actors.

4.2 Geopolitical issues 2: Critical raw materials and the Net Zero

The Net Zero transition is driving a «materials revolution» centred on Critical Raw Materials (CRM), which are also demanded by other transitional sectors (digital, aerospace, and military technologies), creating competition with the «climate change paradigm».
World CRM reserves are concentrated in just a few countries, and this raises relevant geopolitical issues for countries having high external dependency for industrial materials, like EU member states. Major producers of key CRM are China and the fossil superpowers (i.e., U.S. and Russia). Other suppliers include countries from the Global South, characterized by weak institutions, low-quality of governance, and extreme exposure to materials-related conflicts. They can be subject to

political and military instability and increasing tensions in critical areas of the world (JRC, 2025).
In the present disorder of the international system, hampered by the global trade conflict triggered by the US, supply risks and uncertainty are increasing. The international prices of critical materials for Net Zero technologies have not risen significantly, and global reserves indicate no scarcity for most of these minerals and metals (World Bank 2025). In the current international system, geopolitical dynamics and industrial strategies can generate scarcity and create bottlenecks that threaten to hinder the Net Zero industrial transition; this can be exacerbated by competing CRM demand from the digital and military sectors.

4.3 Geopolitical issues: Rearming the world
In terms of investment needs and public resources, the climate-energy transition competes with other independent transitions such as the digital, the demographic, and the public-private finance transition. This pattern is now exacerbated by the «military transition» to which the EU is forced to comply with by the change in the international system of power (EEA 2019; D'Amato 2024). In the post-war period, after the most intense years of the Cold War and the international tensions of the 1970s, the share of military expenditure on GDP declined globally, especially after the collapse of the Soviet Union. In recent decades, military spending in constant dollars has risen sharply across all major powers, including fossil fuel superpowers, and the war in Ukraine has accelerated this trend far beyond the countries directly involved (Fernadez-Villaverde et al. 2024).
The global rearmament dynamic is evident, and aligns with the growing fragmentation of the international system. The recent policy changes triggered by the Trump's administration imposed a redirection of the military future of the EU.
Clearly, this rush to the rearmament of Europe is expected to displace the capacity of the EU's budget and national public budgets to support other expenses of green, social, and R&D funding, with important effects on the transition to the Net Zero (Barbieri et al. 2021; D'Amato et al. 2024).

Concluding remarks
The future of global climate governance depends on the unresolved tension between two competing paradigms: the long-standing fossil energy paradigm, rooted in material power and geopolitical dominance,

and the emerging climate change paradigm, grounded in science-based policies, cooperation, and the protection of global commons. The success of the climate change paradigm is far from guaranteed and hinges on addressing several structural vulnerabilities.
First, the climate paradigm can prevail only if international institutions, scientific cooperation, and collective action manage to counterbalance the strategic power of the fossil superpowers. Second, the credibility of the climate transition depends on the capacity of clean technologies and green finance to scale rapidly in a context of economic uncertainty and geopolitical fragmentation. Third, the open-ended dynamics of the digital/AI revolution raise the question of whether ungoverned technological change will support or destabilize climate-oriented structural transformation, and whether new forms of social governance can constrain their energy footprint.
At the global level, fairness in the appropriation and expansion of the Global Carbon Budget remains a prerequisite for a just transition, yet it is increasingly challenged by national interests and asymmetric innovation capacities. Similarly, critical raw materials risk becoming a new arena of geopolitical competition, potentially undermining the material foundations of Net Zero. Finally, the global rearmament race, especially in Europe, may crowd out essential investments in climate, social policies, and innovation.
Global power, interests, and strategic returns are distributed across the clashing paradigms of «fossil» and «climate change». Given the complexity and the uncertainties of the current geopolitical and technological landscape, we are at a crossroads of seeing whether the «climate change paradigm» can prevail, and enable a shift beyond the current «tragedy of the commons» toward a model of collective stewardship akin to Ostrom's Governing the Commons'.

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