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TECHNOLOGY AND TRANSFORMATION CONFLICTS

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Photo: Marija Ostojic is an artist and media designer whose practice explores identity, migration, and social transformation across painting, film, and participatory formats. This work is part of an exploration of transformation as a complex process that unfolds both internally and externally - not linear, but chaotic, contradictory, and open. Colour carries tension as it accumulates, overlaps, and breaks apart. Transformation does not appear here as a clear before and after, but as a continuous state of becoming.

Further works can be found on Instagram: @mar.i.jaaa.

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NORA KRENMAYR, MARTIN CERNY

Technology and transformation conflicts – an introduction

Technological advancement is often coupled with the increased consumption of materials and energy. Attempts to transform towards a more sustainable economy through green technologies do not appear to be an exception in this regard so far. Electric battery vehicles, the suggested incorporation of artificial intelligence (AI) data centres as part of the twin digital and ecological transition, and renewable energy technologies such as solar photovoltaics and green hydrogen are examples of recently emerging technologies with substantial material and energy demands. Many approaches rely on techno-utopian visions of ‘green’ technologies that presuppose large-scale extractivism and top-down planning (Roos/Hornborg 2024). Market-based and technocentric approaches to the ecological crisis that do not question the existing socioeconomic structures have largely failed to mitigate climate change, while turning it into a new site of capital accumulation. Strategies focused on efficiency gains and technological substitution have reinforced rather than transformed extractivist socioeconomic systems (Bärnthaler et al. 2025), and the expansion of renewable energy and recycling has not curbed rising emissions and resource use while reduction is neglected (Haberl et al. 2020).

The uneven geographical distribution of the extraction, processing, and consumption of materials and energy, as well as waste disposal at the end of the life cycle, risks exacerbating existing global inequalities and creating new forms of environmental and social injustice. Sustaining production through ‘green’ technologies depends on globally asymmetric resource flows that burden marginalised regions with unjust mineral extraction, land-use change, and labour exploitation (Hornborg 2023). Such dynamics ultimately perpetuate existing conflicts and produce new ones. We therefore propose *transformation conflicts* as the conceptual lens of this special

issue: conflicts rooted both in competing visions, interests, and material conditions, and in the distributive consequences of specific technological pathways (Pichler et al. forthcoming). Nevertheless, under favourable social and political conditions, alternative technological pathways to technocentric and market-oriented approaches may prove successful. Low-tech (e.g. Bihouix 2014), convivial technologies (e.g. Vetter 2018), re-use, recycling, and supply- and demand-side reductions could substantially curb energy and material use while fulfilling human needs. Yet, the specific alternatives, their interplay, and the socioeconomic conditions for their broader emergence, as well as illustrating how they can be relevant in transformation conflicts, remain underexplored. Debates on technology in transformation research have so far taken place at a rather conceptual level, with little discussion of specific geographical contexts, and especially how they fit into the global structure of North-South relations, inequalities, and conflicts. For example, in transformation research, there is an ongoing debate on responsible innovations that move beyond an apolitical and technocratic framing of innovation and do not merely reinforce the momentum of economic growth (Genovese/Pansera 2021; Sharma et al. 2025). Kerschner et al. (2018) have discussed which types of technologies meet the requirements of socio-ecological transformation. However, to grasp the global structural power dynamics and the conflicting visions and interests that different technological pathways enable, the concrete conditions under which specific technologies are developed, deployed, and contested have to be examined alongside their social and environmental consequences, and, ideally, illustrated with specific examples, considering their global implications.

This special issue addresses critical issues surrounding emerging technologies often considered pillars of the ‘green and digital’ transformation but which risk becoming unsustainable and exacerbating inequality. Building on a political economy, political ecology, and science and technology studies (STS) perspective, it emphasises the conditions underpinning technological development and deployment and their social and environmental consequences. By examining the material basis of technologies, the issue brings together critical perspectives on topics ranging from critical raw materials for e-mobility and renewable energy to that of e-waste, while including conceptual reflections on the socio-political dimensions

of technology. While most articles focus on the context of the EU as an entity dependent on material imports, the issues addressed here are fundamentally about global connections and resource use patterns, which are rooted in power relations. From a critical perspective, these are questions of uneven development and global inequality: How much technology is needed and where? What are the societal and ecological impacts? Who decides on production and use? And, what does this mean for North-South relations? In the tradition of Gramsci (2005), we refer to the Global South as “spaces and peoples negatively impacted by contemporary capitalist globalization” (Mahler 2017), thus including subjugated peoples and regions in the wealthier parts of the world (Mahler 2018), and subalternised positionalities within global networks of power (Kloß 2017). Rather than focusing on geographical divisions based on country income, the goal is to capture the reality of winners and losers within the global capitalist system. This means attending, not only to the geographical distribution of economic inequalities, but also to moral asymmetries (Pinheiro 2024), specifically regarding who reaps the benefits and who bears the costs of technology implementation.

1. The ambiguous role of technology in socio-ecological transformations

A first challenge is to reflect on the conditions that either enhance or hinder the transformative potential of technologies, the former balancing rather than aggravating socioeconomic inequalities while avoiding environmental damage. This involves considering the production and sourcing of materials, societal-nature relations, property relations, social reproduction, power relations, end-of-life and recycling perspectives, and global justice. As many scholars in the STS tradition argue, technologies are shaped by specific conditions but also shape and enable particular development pathways over time (e.g. Bijker et al. 1987). In a sustainable society, the role of technology would need to fundamentally change, yet the relationship between technology and societal transformations is ambivalent. Critical scholars have long argued that the sustainability challenge in industrial societies requires a fundamental reorientation of society and

the economy rather than mere technical fixes (Haberl et al. 2011). Technological innovation is, it is claimed, necessary but insufficient (Brand/Wissen 2017). While parts of the environmental community advocate for high-tech solutions (e.g. the *Ecomodernist Manifesto* by Asafu-Adjaye et al. 2015), other positions are more cautious and point to aspects of technologies that are considered potentially harmful to the environment and social structures (for the spectrum of attitudes towards technology in sustainability debates, see Kerschner/Ehlers 2016). Across the spectrum of these positions, there is agreement that the ‘desirability’ of technologies should be evaluated against specific criteria; however, due to divergent views on the role of technology in the sustainability transformation, there is little consensus on what these criteria are and how they should be fulfilled. Kerschner et al. (2018) propose criteria of conviviality, appropriateness, feasibility, and viability; Vetter (2018) further develops the criteria for identifying convivial technologies. Such criteria aim to promote technologies that fulfil basic needs, foster solidarity, and are locally produced and environmentally sustainable. Yet, as Pansera (2025) argues, even communities and scholars critical of techno-fixes and committed to sustainability tend to oversimplify the role of technology itself. Discussing whether a given artefact is convivial or not misses the point that technology is actually a complex network of interconnected artefacts, social systems, people, and cultural factors. The role of technology, in his view, is secondary to the capacity of human groups, situated in specific contexts, to come together and decide what kind of society they want to live in. This is consistent with our argument above that technologies must be examined within the specific context of their deployment. Pansera further highlights care and maintenance as dimensions deserving far greater attention than innovation, given that the overwhelming majority of human activity is devoted not to creating the new but to sustaining what already exists. In a similar vein, a notable gap concerns gender and technology: in particular, how gender relations shape the design and selection of technologies (Wajcman 2010).

A persistent obstacle to such reorientation towards care and maintenance is the depoliticisation of technological choices. Innovation is equated with competitiveness in an ‘innovate or die’ logic and also implicitly with growth, leaving little room to ask which innovations are pursued, for whose benefit, and with what consequences (Pansera/Lloveras 2026). Within this

view, ecological outcomes are addressed only indirectly through eco-efficient innovations: profitable high-tech solutions are favoured, low-tech alternatives marginalised, and political choices in technology development obscured (Vetter 2023). Despite decades of unfulfilled technological promises, a persistent technocentric bias continues to legitimise speculative fixes such as carbon capture or low-carbon hydrogen, thus narrowing policy options and deferring structural change (Fressoz 2025). Overall, technology in a sustainable society must be understood not merely as a tool, but as part of a comprehensive transformation that openly and transparently reflects societal goals centred around social justice and ecological sustainability. It needs to question the “blind confidence in technological fixes” (Almazán/Prádanos 2024) as a symptom of the depoliticisation of technological issues over recent decades, in which the dominant social imaginary operates as if technology were an apolitical, neutral tool to be amplified to confront any problem without prior public discussion or political debate. This blind confidence in technological fixes needs critical interrogation, and the re-politicising and reorienting of technology development and governance (Sætra 2023), while a wholesale rejection of technology is neither realistic nor desirable.

2. Structural power dynamics and technology

Technology is thus not merely a set of tools or processes but is rather deeply embedded in societal relations, and so intertwined with political, economic, and socio-technical contexts. Technologies are not inherently transformative or harmful; their impact is contingent on the conditions of their deployment. AI, for instance, can serve as a transformative force or reinforce regressive practices, depending on how it is organised and used. An instrumental approach to technology, such as viewing AI solely as a tool, fails to account for its role in societal transformation. This calls for a non-deterministic approach: rather than drawing distinctions between transformative and non-transformative technologies, the focus should be on the conditions under which technologies operate. Central to any transformation is the need to engage the structural characteristics and power dynamics of society. In this context, the question becomes:

when can a technology be considered transformative? For instance, can a technology be considered transformative if it currently in most cases seems to be merely perpetuating or exacerbating existing power relations rather than altering them? The focus should extend beyond influencing power dynamics to understanding the structural logics governing societal organisation, such as property relations and the organisation of labour. Without addressing these, transformations risk merely shifting power from one group to another without dismantling the systemic problems of racism, patriarchy, and capitalism. Otherwise, the analysis misses the heart of the matter and focuses on technology as the catalyst for the problem, when in fact it is the social ties within which the technology operates, which acts as such a catalyst.

A pertinent example here is the discourse on digitalisation and the green transition, which often fails to question the underlying patterns of production and consumption and thus the corresponding power relations. Instead, it promotes a selective ecological modernisation that deepens the capitalist commodification of nature. Achieving an emancipatory politicisation of the ecological crisis requires counter-hegemonic strategies that promote alternative social and ecological ways of living (Brand/Wissen 2024). In this regard, one can distinguish between technology policies for *transition* and *transformation* (see Scherer, this issue). Transition refers to a rather technical process, such as a shift from one energy source to another without significant implications for social structures and power relations, whereas transformation signifies a fundamental shift in the organisation of society. An energy transition may contribute to societal transformation, but technologies such as electric vehicles can also impede more radical change by consolidating the existing automotive system (Pichler et al. 2021). More generally, transition can involve the consolidation or reinforcement of the existing power structures, building on existing or emerging power relations, whereas transformation is a deliberate challenge to them. A central concern is to make power relations in transformation conflicts visible, particularly in the context of Global North-South relationships. Capitalist centres have access to labour, resources, and sinks in other regions, often in the Global South, along lines of inequality such as class, gender, and race, leading to the externalisation of socio-economic and ecological crises (Brand/Wissen 2017). Technology is not neutral in this process but operates within and

reinforces these power relations. The dependence of technology production on raw materials extracted under problematic conditions illustrates this point. Because extraction tends to be geographically concentrated, it frequently produces ecologically unequal exchanges in which environmental damage more often occurs in resource-rich and often lower-income countries, while economic gains from processing, infrastructure, and technological advances flow to high-income economies (Dorninger et al. 2021; Hickel et al. 2022). These dynamics extend to renewable energy technologies: the manufacturing of solar panels, wind turbines, and related infrastructure require large quantities of minerals such as lithium, copper, and iron ore (Creutzig et al. 2024; Schaffartzik/Pichler 2017).

3. Critical topics: ownership, institutions, and democratic control

First, an aspect of technology development that often receives insufficient attention is the question of ownership structures. The design of technology has social and political consequences, making the systematic exclusion of the majority through private ownership and control of knowledge and data deeply undemocratic (Feenberg 2002; Rikap 2021). Regarding emerging technologies, it is necessary to consider who organises and regulates these advances. This can be described as a conflict between commodifying and decommodifying forces (Polanyi 1944; Wissen 2019). In a commodified technology system, technologies are offered as private services by competing companies pursuing profit maximisation, which makes access dependent on purchasing power and subjects technologies to a growth logic that can counteract positive ecological effects. Decommodification, by contrast, points towards a democratic organisation of production, with technological services accessible to all and offerings aligned to democratically negotiated needs. The decisive question is not solely which technologies are used, but whether the transformation process occurs under public or private control or within other types of ownership regimes.

Second, the institutions that set the terms for technological development and its dynamics do matter. Market-driven innovations alone are insufficient to achieve socio-ecological transformations. Supranational institutions such as the EU play a crucial role in guiding the transfor-

mation process through selection and decision-making among socio-technical development paths (Pichler et al. 2021). Such institutions open the space for combining scientific assessment, public deliberation, and democratic decision-making. This kind of political steering offers the opportunity to better prevent unsustainable development pathways, not only by promoting specific technologies but by prohibiting the use of unsustainable ones (Hausknost/Haas 2019).

Third, the democratisation of technology, especially of large-scale, capital-intensive systems, ultimately depends on broader societal transformation, a process which faces substantial structural barriers. At the same time, the trajectory of high-risk technologies such as AI, carbon capture, and geoengineering makes it imperative to ask whether they can be steered toward genuinely democratic ends, given that depoliticisation and ongoing digitalisation have entrenched a belief in “technological salvation” (Almazán/Prádanos 2024; Hornborg 2024). Open-source low-tech approaches offer counter-hegemonic openings, yet remain confined to niche, prefigurative initiatives, the ability of which to drive systemic change is limited, because they do not address the everyday realities of the majority and underestimate the role of authority and coercion in environmental politics (Bärnthaler 2024). The question of how to strengthen concrete alternatives to the logic of competition and growth thus remains an open one.

4. Contributions to the special issue

The articles in this special issue address these various themes from a range of empirical and conceptual perspectives. What unites them is a commitment to examining the material, political, and social conditions under which technologies are developed, deployed, and contested, with particular attention to global power dynamics and the transformation conflicts they produce, and often also presenting illustrations from specific cases.

Alexandra Tost and Jakob Rammer examine development of the hydrogen production sector in Chile as an example of the tensions between green technology promotion and extractivist dynamics. Drawing on regu-

lation theory and political ecology, they develop a heuristic which distinguishes between reformist, transformative, and structural change, applying it to the region of Magallanes. Their analysis shows that while state and union strategies tend to stabilise existing systems, civil society and Indigenous groups pursue counter-hegemonic alternatives. The transformative potential of hydrogen initiatives, they argue, lies not in the technology itself but in the social conflicts it provokes, which can open space for alternative futures.

Gabriel Eyselein and Theresa Herdlitschka turn to EU critical raw materials policies, claiming that geopolitical thinking increasingly structures EU approaches to resources and nature. They trace how EU framings and strategies have shifted over time, from an initial focus on free-market thinking and economic concerns, through green growth, to a recent strategic and geopolitical logic. Their analysis of symbolic and material dimensions demonstrates how these narratives and policies actively reshape geographic relations and global value chains, transforming both places and nature.

André Baumgart confronts the sustainability dilemma at the heart of the green transition by examining the environmental and human health risks of critical raw materials, including rare earth elements. While demand is driven primarily by high-income countries, extraction and processing are concentrated in China and the Global South, where mining poses risks to ecosystems, workers, and local populations. The article argues that circular economy strategies, particularly demand reduction, can significantly reduce both resource demand and associated impacts in producing and consuming countries alike.

Nora Krenmayr, Benjamin Fleischmann, Gabriel Eyselein, Anke Schaffartzik, and Melanie Pichler examine the future of e-waste in the EU. Based on 20 expert interviews, they identify three imaginaries: recycling, circularity, and sufficiency. Recycling alone, they argue, cannot resolve the escalating e-waste challenge, as rising device production and planned obsolescence outpace recovery efforts. While circularity seeks to close material loops, it remains bound by market logics. Sufficiency, by contrast, challenges the growth imperatives underpinning production and consumption, advocating durable design, consumer repair, and reduced material throughput to confront the root causes of e-waste.

Jakob Scherer analyses the contested politics of EU AI regulation, arguing that the AI Act should be understood as part of broader efforts to renew crisis-ridden modes of production and living. A distinctive feature of the AI debate is its adaptability to different growth projects, both those aligned with the Green Deal and those that are not. While this produces shifts in social-ecological regulatory aspects, the leading position of competition-oriented actor groups remains unbroken or even renewed. The article thus illustrates how AI policy functions as part of a techno-ecological modernisation paradigm.

The **interview with Miriam Fahimi** complements this analysis by exploring AI data centres as central sites of the environmental crisis. It addresses the global distribution of data centres, their energy consumption, and their implications for the environment, as well as the geopolitical power relations expressed in the narrative of data centre growth. It also poses the question as to which strategies a left and feminist tech politics might develop to counter the expansionist logics of big tech.

The **interview with Lina Schmid** turns to Bitcoin and other crypto-technologies, which are often embedded in techno affine development narratives. Starting from foundational technical and political-economic explanations of cryptocurrencies, Schmid discusses their role in global financial politics and their social and ecological consequences. She also addresses approaches for emancipatory and feminist strategies, questioning the promise of cryptocurrencies as tools of financial inclusion in the Global South, and pointing to the conflicts that arise from their material infrastructures and speculative dynamics.

5. Towards a transformative politics of technology?

Taken together, the contributions demonstrate that the role of technology in socio-ecological transformations cannot be assessed in isolation from the political-economic structures in which technologies are embedded, and that issues of power and conflict, along with their global dynamics across the North-South divide as defined above – which peoples and regions reap the benefits and which bear the costs of the global capi-

talist economic system - must be an integral part of any analysis. Several cross-cutting insights emerge.

First, green technologies frequently reproduce rather than challenge existing patterns of extraction and unequal exchange between the Global North and Global South. At least for now, innovation does not appear to balance out inequality. Hydrogen development in Chile (Tost/Rammer), EU critical raw materials policies (Eyselein/Herdlitschka), and the health and environmental risks of critical materials (Baumgart) all illustrate the fact that ostensibly sustainable technologies can perpetuate established power structures.

Second, the distinction between transition and transformation proves to be analytically productive across multiple contributions. Transition technologies such as electric vehicles, solar photovoltaics and green hydrogen may, unless accompanied by more profound changes in power dynamics and social structures, actually stabilise existing systems rather than enable deeper structural change. The contested politics of AI regulation (Scherer) and the e-waste imaginaries (Krenmayr et al.) both show how different framings of technological futures either reinforce or challenge dominant growth logics.

Third, questions of ownership, democratic control, and institutional steering emerge as decisive. The issue of whether technological development occurs under public or private control shapes its potential to contribute to social justice and ecological sustainability. The need to move beyond market-driven innovation towards the democratic governance of technology connects the analyses of EU critical raw materials policies (Eyselein/Herdlitschka), e-waste imaginaries (Krenmayr et al.), data centres (Fahimi interview), and crypto-technologies (Schmid interview).

Beyond these insights, a re-politicisation of technology would open a space for alternative forms of ownership, and enable control oriented towards social and ecological well-being rather than profit (e.g. Rikap 2021). Such re-politicisation could lead to prioritising the deployment of currently available, affordable, and effective technologies, while critically evaluating which technology developments are unnecessary because they fail to support socially equitable and ecologically sustainable goals, before advocating ever more techno-fixes. The central question is therefore how technology is imagined and under what conditions it is deployed,

and who is involved with which interests – and whose views prevail and shape technology technological developments. Further research should deepen the analysis of the conditions under which technologies can genuinely contribute to social-ecological transformations rather than merely modernise existing systems. Key under-explored dimensions include gender and technology, the role of care and maintenance as alternatives to innovation-centred paradigms, institutional mechanisms for democratic technology governance, and counter-hegemonic strategies that can strengthen alternatives to the logic of competition and growth. Bridging the conceptual and empirical insights assembled here with concrete practices of democratic deliberation and technology design, in a way that takes transformation conflicts seriously rather than concealing them, remains a central challenge for transformation research.

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