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Mismatch Crises

Conceptualizing Advanced Energy Transitions

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About the author

Leon Wansleben is a research group leader at the Max Planck Institute for the Study of Societies, Cologne.
Email: leon.wansleben@mpifg.de

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Max-Planck-Institut für Gesellschaftsforschung
Max Planck Institute for the Study of Societies
Paulstr. 3 | 50676 Cologne | Germany

Tel. +49 221 2767-0
Fax +49 221 2767-555

www.mpifg.de
info@mpifg.de

Abstract

Renewable electrification – upstream switches to variable renewable energy sources such as wind and solar, combined with downstream electrification – implies a profound reconfiguration of the energy-society nexus. This is evidenced by significant frictions and political conflicts that intensify at the very moments at which the diffusion of the respective technologies gains pace. Existing transition scholarship has not sufficiently captured these dynamics since it lacks a conception of regime instability and trusts too optimistically in transition progress through economic and policy feedbacks. I leverage the concept of "mismatch" or "structural adjustment" crises from innovation economics to capture situations in which technology adoption happens broadly and quickly, while the development of integrative mechanisms adjusted to the demands of renewable energy lags behind. We see this evidenced by mismatch crises that manifest in three domains: Infrastructures facilitating energy production and use are maladapted to variable power; status orders are destabilized amid growing distributional conflict; and institutions of energy governance are not appropriately reformed. Identifying these manifestations of mismatch crisis does not automatically imply a need to slow down the transition but rather to explore much-needed reforms to establish the integrative foundations for societies powered by renewables.

Keywords: decarbonization conflicts, energy transitions, governance and institutions of energy systems, structural adjustment crises

Zusammenfassung

Die Elektrifizierung des Energieverbrauchs, kombiniert mit Stromerzeugung aus erneuerbaren Energien, impliziert eine tiefgreifende Neuordnung des Verhältnisses von Energie und Gesellschaft. Dies zeigt sich an der Zunahme von Friktionen und politischen Konflikten in genau jenen Phasen, in denen die Diffusion der jeweiligen Technologien an Fahrt gewinnt. Die bisherige Forschung zu Energiewenden hat diese Krisen- und Konfliktdynamiken unzureichend erfasst, weil ihr ein Konzept von Regimeinstabilität fehlt und sie allzu optimistisch auf Fortschritte durch ökonomische und politische Rückkopplungen vertraut. Ich rekurriere auf den Begriff der strukturellen Anpassungskrisen aus der Innovationsökonomik, um Situationen zu erfassen, in denen Technologien in der Breite und mit hoher Geschwindigkeit diffundieren, während die Entwicklung integrativer Mechanismen, zugeschnitten auf die Anforderungen einer erneuerbaren Elektrifizierung, hinterherhinkt. Entsprechend manifestieren sich Anpassungskrisen in drei Dimensionen: Infrastrukturen zur Energieerzeugung und -nutzung sind nicht auf variable Quellen von Energie eingestellt; Statusordnungen sind durch wachsende Verteilungskonflikte destabilisiert; und Institutionen der Governance von Energiesystemen sind nicht angemessen reformiert. Die Identifikation solcher Anpassungskrisen bedeutet nicht automatisch, dass Energiewenden verlangsamt werden sollten; vielmehr gilt es, dringend notwendige Reformen auszuloten, um die integrativen Grundlagen für Gesellschaften zu schaffen, die sich mit erneuerbaren Energien versorgen.

Schlagwörter: Dekarbonisierungskonflikte, Energiewende, Governance und Institutionen des Energiesystems, strukturelle Anpassungskrisen

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1 Introduction

The energy transition presents us with a new puzzle. In several countries, especially in Europe, electricity generation from renewable sources has crossed critical thresholds, now providing the bulk of power for the respective economies. Progress in renewables buildout in these countries is part of a global momentum. The cost of key components of the transition, such as solar cells, batteries, and electric vehicles, has dropped massively. Accordingly, adoption rates of these technologies have risen exponentially. Some social scientists therefore speak of an "accelerated" phase in renewable energy transitions (Sovacool et al. 2025), claiming that "tipping points" have been crossed. Still more vision than reality, some experts see the advent of an "electrotech revolution" (Walter, Butler-Sloss, and Bond 2025) in which renewable generation, new grid technologies, storage, and smart electric devices become integrated into low-carbon energy systems, much like coal, steam engines, and railways complemented each other during the rise of carbon capitalism. While other pathways remain relevant, we can identify the contours of "renewable electrification" as the key process driving decarbonization (Markard and Rosenbloom 2022).

In light of such real progress and technological optimism, the level of conflict around energy transitions is perplexing. Notwithstanding the entrenched enmity towards renewables in the United States, we see growing polarization even in countries with traditionally widely supported and successful transitions.[1] In the United Kingdom, Reform UK promotes fossil and nuclear energy while demonizing wind farms; "net zero could be the new Brexit," as Nigel Farage hopes.[2] As populist actors gain popularity and political power, these polarizations present a serious threat. Green backlash reaches further into mainstream conservatism, which champions various strategies of "climate delay" (Lamb et al. 2020). The German Christian Democrats, a party that had converged on

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1 "Trump Goes Off Script in UN Address, Praising Germany for Returning to Nuclear Energy and Fossil Fuels: 'All Green Is All Bankrupt.'" *Fortune*, September 23, 2025. https://fortune.com/2025/09/23/trump-germany-nuclear-energy-fossil-fuels-un-address/

2 "Nigel Farage Accused of Spreading 'Nonsense and Lies' About Net Zero – as Reform Leader Predicts the 'Next Brexit.'" *LBC*, April 20, 2025. https://www.lbc.co.uk/article/reform-nigel-farage-ed-milliband-net-zero-climate-change-british-steel-brexit-5Hjd5bQ_2/; the AfD in Germany pledges to tear down wind farms: "Wir reißen alle Windräder nieder." *Deutschlandfunk*, January 13, 2025. https://www.deutschlandfunk.de/wir-reissen-alle-windraeder-nieder-afd-wirbt-fuer-ende-der-bisherigen-klimapolitik-100.html

the successful "Energiewende" in the 2010s (Leipprand, Flachsland, and Pahle 2017), have backpedaled, dampening ambitions in the power, road transport, heating, and industrial production sectors.[3] Fueling such adverse politics is an apparent paradox: While green technologies have become ever more efficient, the overall costs, uncertainties, and frictions in rapidly transforming energy systems have grown (Markard, Geels, and Raven 2020; Markard and Rosenbloom 2022).[4]

In this conceptual paper, I offer a new way to look at this co-occurrence of progress and backlash, of technological advancements amid systemic frictions. These contradictory developments are particularly evident in contexts such as Germany and the United Kingdom, where the expansion of variable renewable energy has progressed most and electrification begins to complement such upstream decarbonization. My main contention is that social scientists, as they move beyond analyzing constellations of "carbon lock-in," must embrace an understanding of regime instability while qualifying ideas of positive feedback as driving transition progress. Lock-in presupposes a carbon regime stability that (luckily) no longer exists. Positive feedback mechanisms in technology and policy, on the other hand, assume that transitions can accelerate bottom-up, moving past critical tipping points. This downplays the profound challenges of, and conflictual dynamics associated with, energy system change. I here elaborate the concept of "mismatch" or "structural adjustment" crises (Freeman and Perez 1988) for the case of renewable electrification to concentrate attention on a current blind spot in the transition literature.

This paper advances a broader research agenda (Wansleben, Willems, and Golka 2026). It builds on the idea that renewable electrification is "at the heart of the solution to the climate challenge."[5] The rapid deployment of renewables together with electrotechnology adoption is the best hope for decarbonization at this juncture. But while renewables and electrotech are often portrayed as easy carbon abatement solutions, they come with huge, often overlooked challenges. Accordingly, this paper aims to inform a much needed discussion on the kinds of social and political reforms required to render renewable electrification successful.[6]

3 "Neustart für die Energiewende. Der Umbau des Energiesystems ist zu teuer. Wirtschaftsministerin Reiche will das ändern. Jetzt wird es spannend." *Frankfurter Allgemeine Zeitung*, August 24, 2025.

4 For a popular press take on the topic, see Martin Wolf, "The Great British Electricity Puzzle." *Financial Times,* March 2, 2026.

5 "Energy Is at the Heart of the Solution to the Climate Challenge." *Intergovernmental Panel on Climate Change*. July 31, 2020. https://www.ipcc.ch/2020/07/31/energy-climatechallenge/. Jacobson (2026, 1) suggests that "about 90% of anthropogenic air pollutant emissions and 75–80% of anthropogenic climate-damaging emissions originate from energy."

6 That said, I concur with pessimistic views that expect significant warming and a deepening of ecological crises (e.g., Beckert 2023). But given the wide consensus (and sometimes fatalism) regarding this failure, the more pressing research question at the current juncture is not *why* we are failing (for which many plausible reasons can be found) but *how* some steps towards climate

The next section argues for a switch in theoretical vocabularies from carbon lock-in and positive feedback to structural adjustment crises as key characteristics of rapidly transforming, destabilized energy regimes. I list several reasons why technology adoption unfolds more quickly than the requisite changes in infrastructures, social structures, and institutions that the transition to a fundamentally different energy regime demands. In the main part of this paper, I spell out structural adjustment crises associated with current levels of renewable electrification in advanced transition contexts. I close by defending my approach against a few possible objections.

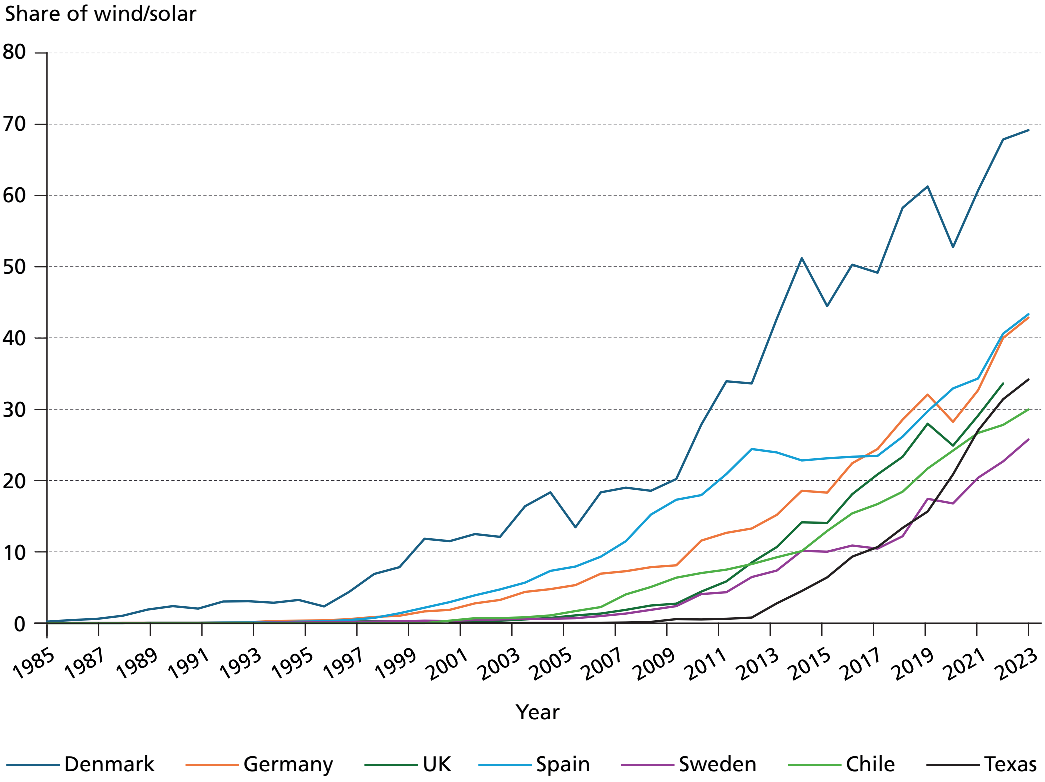
2 Beyond "carbon lock-in": From acceleration to mismatch crises

The term "transition" is highly contested. In a much discussed recent book, Jean-Baptiste Fressoz (2024, 222) argues that "transition is the ideology of capital in the twenty-first century." With global overall *growth* of fossil extraction and consumption, and ubiquitous talk of the "transition" as an empty promise for climate change mitigation, skepticism is justified. Theoretically, assuming a phase transition from one equilibrium to another is highly problematic.

However, a more open concept of energy systems *being in transition* is justified. Starting with changes in the electricity generation mix since the 1990s under conditions of stagnant overall demand, significant substitution has happened in countries like Denmark, Ireland, Germany, the United Kingdom, and Spain. Concentrating only on wind and solar as "variable renewable energy" (VRE), these sources now cover between 30 and 70 percent of electricity demand in the respective countries (Figure 1), up from virtually zero thirty years ago. While innovation and fast adoption of electrotechnology by and large happen elsewhere, the respective European countries have more recently seen an accelerated uptake of batteries, EVs, and heat pumps. The nexus between *upstream decarbonization* of power and *downstream electrification* is complex, but it has political as well as techno-economic underpinnings. Not only do climate policy actors aim to combine one with the other to fully decarbonize energy systems; VRE adoption also requires and renders attractive (e.g., via price mechanisms) investment in supply-responsive smart electrotech. This can shift the incentive structures in energy-related sectors (Goedeking and Meckling 2024). These different yet unequal processes of adoption unfold amid a general process of efficiency gains and cost reductions. Green technologies have become much better at turning environmental energy into useful energy (e.g., through larger wind turbines, better battery chemistry, better computational control). Together with economies of scale and Chinese industrial policy, this has dramatically improved

change mitigation can be accomplished under adverse conditions and circumstances (Adloff 2025). Clarifying the societal challenges of renewable electrification – a fathomable problem compared to sustainability *tout court* – can help in this task.

Figure 1 Wind and solar as share of overall electricity generation



Sources: Our World in Data; US Energy Information Administration.

the economic case for renewable electrification, measured in terms of levelized costs of energy (LCOE) for generation and total costs of ownership (TCO) for equipment like heat pumps (Jacobson 2026).

Throughout the paper, I will primarily focus on contexts where the transition is in an "acceleration" phase (Markard and Rosenbloom 2022; Sovacool et al. 2025), with high levels of variable renewables penetration (above 30 percent) and ambitions for virtually full decarbonization of energy supply, and where incipient and highly unequal patterns of downstream electrification can be observed.[7] I choose these contexts because, regardless of the remaining distance to "net zero" (Fressoz 2024), transitions in these countries already pose significant challenges for entrenched carbon orders (Sovacool et al. 2025). The consolidation of energy transitions has raised rather than lowered the

7 Upstream, I concentrate on variable renewables, such as wind and solar, because they are the key drivers of change in generation mixes. Neither hydro nor nuclear power plays a sizable role. That said, countries with large – even if more or less stagnant – hydropower sources have less difficulty integrating VRE. For heuristic reasons, my attention is primarily on countries with less benign conditions.

degree of political contestation, and the adoption of ever more efficient green technology co-occurs with rising system frictions and costs. The question I aim to answer in this paper is how to conceptualize this constellation.

What happens after "carbon lock-in"?

While traditionally focused on analyzing "carbon lock-in" situations, the transition literature has recently moved beyond this notion to study "accelerating" transitions (Markard and Rosenbloom 2022; Sovacool et al. 2025). However, this new literature does not sufficiently theorize the instabilities created by acceleration (Grubert and Hastings-Simon 2022). This is most evident in its continuing reliance on concepts of policy or technology feedback that fail to explain the broadening as well as the deepening of frictions and crises at these stages (Markard and Rosenbloom 2022). Heightened conflict, in my view, results precisely from the incapacity of policy and technology feedbacks to induce reforms that would establish the requisite infrastructures, distributional settlements, and institutions that can stabilize a society fed by renewable power. I will first address this literature before turning to my conception of structural adjustment crises as an alternative approach.

What happens if we move beyond carbon lock-in? The latter concept has guided research on energy transitions ever since Gregory Unruh's (2000) pioneering work. In sustainability transition studies, lock-in means that infrastructures, institutions, and deep-seated behaviors (e.g., routines) "generate a mutually reinforcing consistency, with each sphere and the system as a whole becoming increasingly resistant to change" (Seto et al. 2016, 434). In Frank Geels' prominent "multi-level perspective" (MLP), lock-in is associated with the "regime" and its embedding in a broader "landscape" of institutions and structures (Geels 2019; Loorbach, Frantzeskaki, and Avelino 2017). The political economy version focuses on energy sector interest groups. "Brown" incumbents, such as firms involved in carbon extraction, fossil-based power generation, carbon-based production processes, or the sale of carbon products (like combustion engine cars), predominate over "green challengers," such as solar or wind farm generators, electrotech producers, and other firms benefiting from renewable supply chains (Green 2025; Schwander and Fischer 2024). Incumbency is associated with high structural and instrumental (e.g., lobbying) power (Mildenberger 2020; Stokes 2020). Institutions can reinforce – but sometimes also reduce – these power asymmetries (Finnegan 2022; Finnegan et al. 2025).

Certainly, even in advanced transitions, some degree of "carbon lock-in" remains in "hard-to-abate" sectors.[8] However, the literature has widely acknowledged that the con-

8 For instance, some industrial sectors, especially those relying on extremely high temperatures or carbon as "feedstock," have not identified any viable transition pathways under current global economic and technological conditions. Moreover, in sectors like road transport, where supe-

cept has lost its purchase as a way to capture overall dynamics. Carbon-dependent infrastructures, institutions, and behaviors are no longer in "equilibrium" or make up a stable regime, as prominent conceptualizations of lock-in suggest (Seto et al. 2016, 445). Rather, in the countries mentioned, renewables nowadays dominate electricity production on many if not most days of the year; powerful alliances have formed around these technologies, sometimes including former fossil incumbents (Lindberg and Kammermann 2021) and with significant influence on politics. In downstream sectors, fossil producers and sellers of fossil technologies (such as combustion engine cars) still tend to prevail but have lost their secure market positions (Fischer 2025). The firms and households participating in renewable electrification often enjoy techno-economic advantages over carbon-dependent actors.

A significant strand in the transition literature has endorsed the concept of "acceleration" to describe this new phase (Lindberg and Kammermann 2021; Markard and Rosenbloom 2022; Sovacool et al. 2025). This concept puts the emphasis on technological maturity and fast market penetration (Geels 2019, 6). While it thus captures the recent momentum in transitions, it fails to articulate the distinct challenges that arise from it (for an exception, see Markard, Geels, and Raven 2020). Some works note that "system reconfiguration" is more demanding than technology diffusion, and that different sectors of the larger energy system may transform at different speeds, creating frictions (Bolton and Poulter 2025; Sovacool et al. 2025). However, significant scholars in this literature maintain a problematic faith in technology-driven progress. As an exemplification of this, Geels (2026, 6) trusts that "the accelerated diffusion of new technologies may … galvanise subsequent transformations in beliefs, institutions, and power structures."

At the theoretical level, such optimism is justified with the popular idea of *positive feedback*. Stemming from innovation economics, this concept describes self-reinforcing cycles between technology diffusion and maturation, primarily expressed in terms of upward-sloping adoption curves and downward-sloping cost curves. Sustainability transition scholars have stressed the importance of protected niches for triggering such feedback effects (Geels 2019); research and development policies are critical to get the transition off the ground (Edmondson, Kern, and Rogge 2019; Laes, Gorissen, and Nevens 2014). Political economists have extended the idea by focusing on political mechanisms, especially policy feedback (Jacobsson and Lauber 2006; Jordan and Moore 2020; Schmid, Sewerin, and Schmidt 2020), whereby support coalitions for a policy grow with its adoption (Pierson 1993). Matthew Lockwood (2022) discusses institutional configurations that support or mitigate such feedbacks (see also Lockwood et al. 2016; Meckling, Sterner, and Wagner 2017).

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rior "green" alternatives are sometimes available, carbon still predominates, reflecting precisely those infrastructural, behavioral, and interest group-related mechanisms that sustainability studies and political economists have in mind. In his PhD, Stephan Stuckmann explores these issues (e.g., in an unpublished paper entitled "Struggling at the Decarbonization Frontier: Examining the Coordinative Politics of Green Industrial Policy Along Germany's Chemical and Steel Industries," Max Planck Institute for the Study of Societies, Cologne).

As intriguing as the idea of positive feedback is in the study of early transitions and within delineated subsectors, it is limited in its capacity to capture the problematic relationships of technology trajectories to a broader energy regime. In naïve versions, the literature seems to imply that positive feedback will reach a tipping point, when the overall regime can flip (Sovacool et al. 2025, 9). This not only neglects the kind of carbon opposition that may mount in advanced transitions, and which requires distinct political responses (Breetz, Mildenberger, and Stokes 2018; Edmondson, Kern, and Rogge 2019);[9] another problem is that systemic changes – grid overhaul, market redesign, new distributional settlements – demand a different kind of political agency than the advocacy for certain technologies can provide. System change also demands far greater organizational capacities and macroeconomic resources (Gabor and Braun 2025) than any of the investigated feedback processes can mobilize (Bolton and Poulter 2025; Wansleben, Willems, and Golka 2026). Some scholars try to rectify these limitations by suggesting that feedbacks can spill over from one sector to another, via "coalition cascades" (Meckling and Goedeking 2023), or by feedbacks spanning multiple policy domains (Edmondson, Kern, and Rogge 2019). However, the conditions for such coalition expansion remain unclear (Goedeking and Meckling 2024), while the literature seems to maintain a strong bias towards technological solutions (Andersen et al. 2023; Sinsel, Riemke, and Hoffmann 2020), rather than institutional and public goods ones, in its authors' thinking about system change.

In short, then, transition dynamics are poorly theorized in the unstable phase following carbon lock-ins; the concept of positive feedback is unsuited to understanding rather contested situations when renewable electrification has already made considerable inroads into carbon legacy systems while deeper structures, infrastructures, and modes of political steering have failed to adapt sufficiently. It is this mismatch that I put at the center of my own conceptualization.

Mismatch crises

The concept of structural adjustment or mismatch crises as I use it here is derived from Christopher Freeman's and Carlota Perez's work and further elaborated for the case of renewable electrification. It consists in two rather straightforward ideas: First, while some innovations are contained in certain sectors, others more fundamentally challenge the political-economic order. Freeman and Perez (1988) capture this by distinguishing be-

9 The notion that advancements in renewable electrification provoke "negative feedback" aligns more closely with the idea of mismatch crises developed in this paper. However, while negative feedback implies that "the existing and well-established networks between incumbents and policymakers ensure the stability of the regime" (Edmondson, Kern, and Rogge 2019, 9; essentially maintaining or re-establishing a situation of carbon lock-in), the concept of mismatch rather emphasizes persistent regime instability and conflicts as pressures for renewable electrification remain strong and have already irreversibly altered key sectors and areas of energy use.

tween four types of innovations: incremental innovations, radical innovations, new technology systems, and changes in techno-economic paradigms. Incremental innovations concern improvements in established production lines; radical innovations bring about new products; new technology systems give rise to entire new markets; and techno-economic paradigm shifts imply that significant parts of the economy and their broader social embedding are being challenged. Second, and more importantly, any techno-economic paradigm change will lead to prolonged "crises of structural adjustment" or "mismatch crises" (Freeman and Perez 1988, 47). By this the authors mean a lack of synchronicity between the accelerated diffusion of a new technology, its dramatic economic effects, and the speed with which key constituents of social, political, and economic order can adapt (Dolata and Werle 2007, 26). I will now turn to these two components of the concept to render it useful for the analysis of renewable electrification.

First, as we enter the advanced phase of VRE expansion together with significant downstream switching to electrotech, the notion of techno-economic paradigm shift becomes an appropriate descriptor for the transition. Why is that? On the one hand, the materiality and techno-economics of variable renewable energy start to impose themselves in the areas of production, distribution, and consumption, revealing deep frictions with carbon/nuclear systems (Balmaceda et al. 2019; Mitchell 2013).[10] In Sinsel et al.'s (2020, 2272) summary, VRE are distinct because

> VRE generator output (1) varies due to its primary resource variability [of wind and sun] and (2) is unpredictable; (3) VRE generators are modular and small in size; (4) they are location-constrained; (5) unlike conventional generators, VRE generators are mostly non-synchronous types; and (6) they have low short-run costs.

The nature of how wind turbines and solar panels capture environmental energy and turn it into useful energy thus is fundamentally different from carbon/nuclear energy generation, and so is the process of distributing and pricing energy, with capital expenditures ("capex") dominating the cost structures of VRE generation. Add to that profound transformations on the demand side as energy use switches from the often passive load covered by central production units, large-scale fossil combustion in factories, and local combustion in boilers or cars to the emergence of smart distributed energy system units in homes and sometimes in single electrotech appliances. In short, renewable electrification entails sweeping changes at the "system" level, as a growing number of experts recognize (IEA 2024; Sinsel, Riemke, and Hoffmann 2020; Verzijlbergh et al.

10 The term "fossil-nuclear systems" certainly lumps together extremely diverse energy orders, with distinct energy materialities, large-scale systems, capitalist structures, and political institutions. For instance, much has been written about the particularities of coal energy systems and "coal-fired social contracts" (Kahle 2024; Mitchell 2013); about oil as simultaneously concentrating political-economic power while globalizing energy in unprecedented ways (Coronil 1997; Mitchell 2013; Mukoyama 2024); about the tightening of industry-defense-state relations in the development of nuclear (Hecht 1998; Mayntz 1993; Uekötter 2022; Winner 1980), and how nuclear provoked the rise of new social movements (Beck [1986] 1996); and also about gas as the latest hydrocarbon to be exploited at scale (Högselius 2023; Högselius, Åberg, and Kaijser 2013).

2017). Indeed, there exists an older tradition of thinking about these radical transitions towards energy systems that are reliant on solar power harvested with decentral modular technology.[11] But what we can see today are the actual affordances of this change, rather than a realization of the utopias associated with it.

Moreover, in advanced transitions, the respective system changes have significant implications for almost *all* energy system participants, not just involving upstream generators and the movements (Morris and Jungjohann 2016), experts (Aykut 2015; 2019), and political/interest groups (Nahm 2022) participating in the struggles between renewables- versus fossil-generated electricity. There are indeed a few "hard-to-abate" sectors, where fossil combustion and the use of carbon as feedstock remains extremely difficult and expensive to replace. Beyond that, though, renewable electrification affects every type of actor – energy producers as well as their upstream supply chains; transmission operators/distributors; and industrial as well as private users. Not only does the ongoing growth of VRE further marginalize or extinguish fossil extraction sectors like coal, with profound (e.g., regional) repercussions (Beckfield and Evrard 2023), while shifting supply chains to other countries/regions, most notably China; many industrial sectors also see changes in how and what they produce (Kupzok and Nahm 2024). Due to this much larger socioeconomic reach of renewable electrification, we observe more profound impacts on growth models, patterns of distribution, and institutions. Taken together, the fact that renewable electrification goes hand in hand with radical changes in the materiality and techno-economics of energy, and that this process affects almost all actors in the energy system, makes this a techno-economic paradigm change *par excellence*.

Why would such a techno-economic paradigm shift induce structural adjustment crises, especially at the stages of accelerated technology adoption seen in some countries today? Again, we can rely on different strands of energy research and beyond to render this idea plausible. First, it is very often the case that technologies spread more quickly than it takes to (re-)construct the large-scale infrastructures to support them. Building cable lines, transformer stations, new control centers, and the whole soft infrastructure a new infrastructure entails takes longer than building a wind park or installing solar panels. This is why a growing technical, but also social science, literature has shifted attention from technology issues to grid and system issues, emphasizing the growing mismatches between carbon and nuclear energy systems and the infrastructural demands associated with renewable electrification (IEA 2024; Sinsel, Riemke, and Hoffmann 2020; Verzijlbergh et al. 2017). From a social science angle, Grubert and Hastings-Simon (2022, 5) note that ambiguities and frictions emerge "when the penetration of the new infrastructure reaches a level where it imposes operationally meaningful constraints on the existing system through incompatible characteristics." The infrastructural deficiencies were less apparent in early transitions, as VRE impact remained contained while

11 For instance, Hermann Scheer (2003), the pioneer thinker of a solar economy, envisioned regionalized value chains, the re-emergence of a large primary sector, local grass roots democracy, and a shift from labor to leisure. This vision seems implausible at this point.

fossil-nuclear logics still predominated. However, the frictions become palpable in what Grubert and Hastings-Simon call "mid-transitions" and what the transition literature, as discussed above, calls "acceleration."

Second, recent political economy discusses the broader and socioeconomically more consequential distributional struggles as renewable electrification reaches beyond the power sector proper (Kelsey 2018; Kupzok and Nahm 2024). Distributional conflicts articulate the socioeconomic fault lines associated with structural adjustment crises as inequalities in the conditions for participating in renewable electrification become apparent, along firm, sector, class, and country lines. For instance, sector-level conflicts between incumbent producers of fossil assets and challengers offering electrotech can aggregate into geopolitical conflict lines between incumbent "carbon states" and up-and-coming "electro-states" (Mitrova and Corbeau 2025). Energy-related distributional struggles also intensify at the household level as families engage with the process of renewable electrification on structurally unequal terms, with richer households leveraging their higher financial, educational, and social capital (Kuhn and Schlattmann 2024). These inequalities in turn produce deep cultural frictions as social groups adopt very different imaginaries of renewable electrification. Those that emphasize opportunities are juxtaposed against those that frame the transition in terms of "retrospective nostalgia," "static presentism," and/or "fatalistic resignation" (Adloff 2025). In structural adjustment crises, unequal speeds in technology adoption along socially salient – mostly class – fault lines produce divergent cultural understandings and perceptions of the future (Suckert and Ergen 2022).

Third, a growing number of authors also note structural adjustment crises at the level of governance institutions. For instance, Markard, Geels, and Raven (2020) identify rising coordinative demands as electricity systems adapt to higher shares of VRE and energy transitions move beyond the electricity generation sector, noting the limitations of liberal, market-based approaches to solve these coordination problems. Wansleben, Willems, and Golka (2026) particularly focus on the need for planning in these situations, which is poorly addressed by current institutions. Bolton and Poulter (2025) exemplify this by revealing the mismatches between the need for massive distribution grid upgrading and current versions of "incentive-based" grid regulation in Great Britain. Other authors focus on the inadequacy of financing mechanisms for fundamental system rebuilding (Christophers 2024; Gabor and Braun 2025; Valenzuela 2025) or the lack of distributive policies that effectively compensate the current losers of renewable electrification (Wansleben and Terhorst 2025). Governance failure produced by maladapted institutions can produce technical problems (in the extreme case, blackouts), higher system costs, and a deepening of unresolved socioeconomic and political conflicts.

In short, then, not only should we recognize renewable electrification as a sweeping change affecting almost everybody with a stake in energy – a techno-economic paradigm shift, according to Freeman and Perez's vocabulary – we also have strong indications that this process brings with it structural adjustment crises of the kinds that the two innovation economists had foreseen. This is because infrastructures are rebuilt more slowly than technologies diffuse; participation in renewable electrification shows systematic inequalities and thus produces socioeconomic fault lines; and the institutions of energy governance are not adequate in meeting the demands of a dynamic transition towards a radically different energy regime, leaving key problems and conflicts associated with the transition unresolved.

The remainder of the paper will primarily serve to deepen the analysis of infrastructural, social-structural, and institutional dimensions of structural adjustment crises. Its purpose is to show that, as we turn our attention to advanced transition contexts, identifying mismatch crises across these dimensions provides a useful frame of analysis and assessment, revealing why obstacles increase in an otherwise promising and extremely dynamic process of change.

3 Structural adjustment crises in advanced transitions

I concentrate in my following discussion on infrastructural frictions, energy-related status conflicts, and institutional mismatches. I treat these as three overlapping but distinguishable aspects of structural adjustment crises that can be conceptualized according to distinct theoretical ideas.[12] I will often rely on the German and British contexts for illustration but also cite literatures with broader empirical scope.

12 The three dimensions mentioned are, of course, overlapping. Infrastructures are embedded in institutions not least because networked components can only interact based on regulation – Alfred Chandler (1977) saw the rise of modern corporations in the railway sector as originating from the need for infrastructural coordination. At the same time, institutions can only become effective in infrastructured environments that facilitate the formation of routines and habits (Edwards 2019). Infrastructures also enable and disable certain patterns of (highly unequal) asset ownership, production, and consumption, thus being deeply entangled with socioeconomic structure (Chancel 2025). And as many have argued, it would at best be naïve to treat institutions as independent from actual distributions of power, which reflect socioeconomic inequalities. Equally though, interests, orientations, and expectations are formed by, and become effective via, institutions (Hall 1986). Despite these interdependencies, however, infrastructures, socioeconomic structures, and institutions help us to study mismatch crises from complementary analytic perspectives. With an "infrastructural gaze" we foreground large-scale, backgrounded materialities distributing energy (Hughes 1983; Star 1999); when turning to socioeconomic structure, we prioritize (shifts in) positional orders among social actors in larger social spaces (Bourdieu [1972] 1977; 2005); and from an institutionalist angle, we study complex conflict settlements, established formulas for distributing benefits and costs, and the role of coercion as well as legitimacy to enforce rules (Offe 2004). I discuss each of these dimensions in turn, indicating connections where appropriate.

Infrastructural frictions

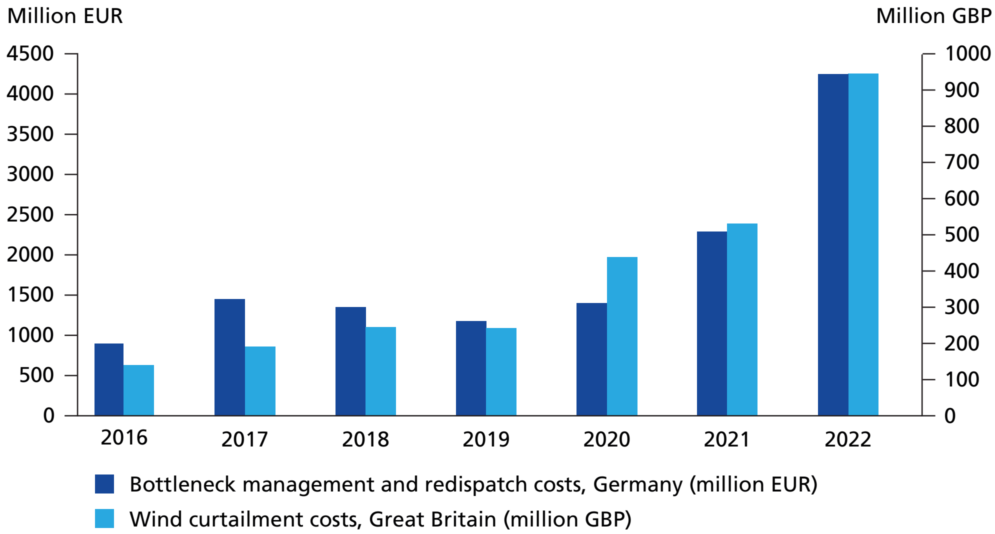
The concept of *lock-in* discussed above is strongly associated with the idea that carbon energy infrastructures operate in the background, entail complex interconnections (e.g., with user technologies), and have extremely long lifespans (Seto et al. 2016, 427–8). Such backgrounding, the facilitation of flows, and the seemingly endless running times of infrastructures are being disrupted by renewable electrification at advanced stages. This is a key sign of regime instability (Grubert and Hastings-Simon 2022).

Most straightforwardly, whenever more VRE is fed into existing electricity grids, this produces problems of various sorts. The geography and weather-dependent timing of generation overburdens existing transmission and distribution grids that were built for more centralized, dispatchable, or baseload generation, usually closer to the centers of demand (Sinsel, Riemke, and Hoffmann 2020; Verzijlbergh et al. 2017). VRE also disturbs established "control room" practices that were developed by utilities, in the course of the twentieth century, to synchronize grid frequencies and manage sudden shifts in generation or load (Cohn 2017; O'Malley 2022). In consequence, the mismatch between VRE and legacy grids produces costs and instabilities of various sorts. Redispatch costs or transmission congestion charges are a particularly visible indicator of these frictions, which arise from compensating generators that cannot deliver power to their customers and the parallel need to dispatch more expensive power from (fossil) generators closer to the demand location (see Figure 2 for Germany and Great Britain). As discussed below, while grid congestion and redispatch appear to be technical issues at first sight, they increasingly exert influence on the larger politics of energy by raising system costs.[13] At the same time, instabilities due to maladapted frequency stabilization and a lack of dispatchable backup can become palpable, as the Spanish outage in spring 2025 exemplified. Such disruptions, which frequently render otherwise taken-for-granted infrastructures visible (Star 1999), not only raise formidable engineering issues but also disturb the deep sense of security associated with uninterrupted availability of power.

Second, massive grid expansion and upgrading are required for VRE buildout and electrification. These needs arise not just for power transmission but even more so for distribution, where insufficiently extended and upgraded networks (e.g., with smart meters) constrain the use of EVs, heat pumps, and batteries. As discussed above, since VRE harnesses environmental energy, advanced (computer-supported) infrastructural facilitation plays a much bigger role in a target system with more VRE (Bolton 2018). The frictions produced by these pressures for infrastructure renewal are articulated in different forms. On the one hand, inertia in the legacy infrastructures and the various political, economic, and social forces connected to them prevents sufficient investment,

13 In more abstract terms, curtailment costs, and more specifically marginal curtailment costs, increase the costs of energy overall as each added unit of generation – a wind turbine or solar panel – will service less end-customer energy load. With rising (marginal) curtailment, the overall costs of the transition thus increase (Chyong and Newbery 2025).

Figure 2 Redispatch/curtailment costs in Germany and Great Britain



Sources: BNetzA (Germany), Hawkes (2026) (Great Britain).

enlarging the gap between demands and available infrastructure.[14] Simple indicators of this are the redispatch costs mentioned earlier as well as long connection queues for generation, storage, and load, as well as delayed rollout of smart meter technology. At the same time, to the extent that infrastructure building *does* happen or is planned, resistance and obstacles mount. A plethora of studies have documented local resistance to wind farms, utility-scale solar, and transmission or distribution line projects (Buckley and Colvin 2026; Cohen et al. 2016; Neukirch 2020; Stokes et al. 2023). The literature discusses various factors explaining variations in local resistance – including (perceptions of) individual benefits or costs, partisanship and ideology, place attachment and social identity (e.g., associated with a rural-urban divide). Apart from these variations, though, the deeper cause of resistance is that a large-scale expansion of visible, space-consuming infrastructure stands in conflict with both structural and cultural dispositions of mature carbon societies, and this *despite* large majorities in the respective societies supporting renewable energy transitions in general (Stokes et al. 2023). It is *not* carbon versus green interests per se that drives conflict here (Green 2025) but the adjustment costs that arise from building a new large-scale and visible infrastructure. Moreover, citizen resistance to infrastructure expansion is just one obstacle; the difficulties around mobilizing resources for massive infrastructure buildout are as important. In Germany, cost estimates for transmission grid expansion until 2045 are EUR 360 to 390 billion, with investment of GBP 60 billion projected up to 2030 in Great Britain – and transmission grid financing

14 This is one of the reasons why countries that can "leapfrog" to renewable electrification may have strategic advantages over countries with massive and deeply entrenched carbon-nuclear infrastructures; "infrastructural leapfrogging" may be even more important than technological leapfrogging.

is just one of the many demands on scarce resources.[15] Simply put, societies accustomed to "naturalized" and still by and large operative carbon energy infrastructures are not well positioned for a radical infrastructure renewal. This produces growing frictions.

Finally, while some existing fossil infrastructures can be repurposed for VRE and electrification, others will fall into disuse (Grubert and Hastings-Simon 2022). Transition scholarship has noted a difference between transformations allowing for repurposing/adaptation versus transformations requiring more radical overhaul (Geels and Kemp 2007; Sovacool et al. 2025, 4). But there has been little discussion until now about the disruptive dynamics of *infrastructure stranding.* Infrastructures have longer lifetimes than individual assets; they also have public goods functions, enabling the use of upstream (energy generation) and downstream (energy demand) assets.[16] These temporal and public goods features produce distinct problems for renewable electrification processes; stranding whole infrastructures creates even higher potential for conflict than stranding individual (even if broadly owned) assets.[17]

Infrastructural frictions thus are one major dimension of structural adjustment crises. Especially (though not only) in advanced transitions, the inadequacy of legacy grids for growing VRE penetration, the pressures for and resistance to infrastructure construction, and the disruptive processes associated with infrastructure stranding all produce conflicts that transcend the technical realm and feed into politics. Accordingly, infrastructures are one dimension through which we can understand why the unmaking of carbon lock-in and the success of technology-specific feedback loops exacerbate rather than reduce conflict. Rising system costs, produced by redispatch and other necessary grid management measures on maladapted grids, produce distributive and fiscal conflicts. Opponents of renewables find new (dubious) grounds for campaigning against what they portray as expensive green energy (thus attributing the friction

15 These figures are taken from the German transmission grid operators' "Netzentwicklungsplan Strom 2037 mit Ausblick 2045, Version 2025," p. 243, https://www.netzentwicklungsplan.de/nep-aktuell/netzentwicklungsplan-20372045-2025; and from "Upgrading the Grid: The Great Energy Transition in Numbers." *Guardian,* December 11, 2025.

16 Nina Lopez-Uroz explores infrastructure stranding for the case of gas distribution grids (e.g., in her unpublished manuscript "The Achilles Heels of Infrastructural Power: How Gas Distributors Navigate the Heat Transition," Max Planck Institute for the Study of Societies, Cologne).

17 This is illustrated well for the case of gas distribution grids. Grid operators fear significant economic losses on long-term assets. The problem is heightened by the obligation, according to German law, for example, to maintain the pipelines as long as customers need them. In principle, it can be solved, from the perspective of the grid operator, by distributing the infrastructure costs to a shrinking customer base in the framework of regulated user fees. But not only do rising user fees multiply the costs for individual customers and render infrastructure use uneconomic; more problematically still, the remaining households will very likely be poorer ones with less capital and hence lagging behind others in investing in renewable assets (Kuhn and Schlattmann 2024). Should infrastructure operators plan to retire grids, enabled by recent legal reforms, the timelines may be uncoordinated with users, who, in the extreme case, will invest in new carbon assets only shortly before pipelines are closed. Such a scenario would create significant individual and macroeconomic costs.

to the despised technologies rather than the unfit legacy system). Instability problems can feed even more adversarial politicization against renewables, as happened after a winter storm outage in Texas in 2021 (Powers 2024) and more recently after the Spanish blackout in April 2025.[18] Local resistance against infrastructure investments and their social costs provides yet more grounds for anti-green backlash. We see a clear pattern whereby right-wing populist parties aim to position themselves as the spokespersons of these diverse local resistances (Otteni and Weisskircher 2022). Finally, the prospect of carbon infrastructure stranding does not just mobilize the immediate infrastructure owners but also creates significant costs and uncertainties among extremely heterogenous groups, who are variously attached to these infrastructures via their own human capital as well as physical investments (Wansleben and Terhorst 2025). Both these costs and uncertainties provide fertile ground for anti-renewables politicization.

Energy-related status conflicts

As noted above, socioeconomic structures are increasingly affected by renewable electrification, producing much broader distributional, (geo-)political, and cultural conflicts than seen during early, more contained transitions. One way to conceive of this process is in terms of a destabilization of carbon-based status orders. Status, following Max Weber ([1921] 1976), implies the existence of legitimate hierarchies, of positions within unequal structures associated with "honor." Social scientists have long been interested in situations in which the distribution of sheer economic resources changes while status orders remain entrenched, producing conflict in processes of social change (Lockwood 1964). Arguably, we can see such a constellation in the current accelerated transition, in which the techno-economic advantages are increasingly shifting in favor of developers and adopters of renewable electrification, provoking a misalignment with existing energy-related status orders that still benefit – symbolically, institutionally – fossil producers and consumers. Status conflicts are particularly fierce and open up opportunities for adversarial politicization.

The concept of status conflicts can be applied widely. It should capture, among other things, the situation on markets and in sectors where firms usually maintain stable positions vis-à-vis others (Fligstein 2001) and produce according to routine schedules (White 1981) (see also Aspers 2011; Beckert 2009). Due to these status orders on markets, incumbents rarely take up the opportunities offered by technological innovations – though sometimes they do (Lindberg and Kammermann 2021). Their regular resistance or hesitancy arises not just from the costs of switching to new assets and energy forms: Any change in products, production methods, value chains, or the like is associated with the risk of

18 "Minister Warns Against Blaming Spain's Blackout on Renewables." *Guardian*, April 30, 2025. https://www.theguardian.com/world/2025/apr/30/environment-minister-warns-against-blaming-spain-blackout-on-renewable-energy

losing incumbent positions. Therefore, more often than not, it is challengers that take up technological innovations, to disrupt market orders and dethrone the incumbents, while the latter are on the defense. We saw this first in the energy sector proper (Stokes 2020) and see it now in an increasing number of sectors in which challengers effectively use electrification as a strategic opportunity to disrupt entrenched orders while incumbents try to defend their status, sometimes against unavoidable technological trends (Fischer 2025). This unsettling – in strong contrast to situations of carbon lock-in with stable status hierarchies – can partly explain the force of enmity at the current stage, as reflected, for instance, in intensifying geopolitical conflicts between states with different stakes in carbon orders versus renewable electrification (Mitrova and Corbeau 2025).

Status conflicts also intensify among private households during advanced transitions as the distributional consequences deepen, demands on behavioral changes grow, and contestation around imaginaries of energy intensifies. "Prosumerism" becomes much more widespread with plummeting costs of solar and its extended "behind-the-meter" use case due to batteries and heat pumps; electrification, especially in vehicle use and heating, accelerates with technological maturation and advantageous TCOs; in systems with growing shares of VRE, flexible energy use in response to variable generation becomes economically more rewarding; and advancements in computation allow such flexibilities and coordination between devices and grids to be exploited. As noted, for some experts, these different elements converge towards a radically new idea of citizens' involvement in energy, who will manage their own (interdependent) energy units with various smart generation, storage, and consumption appliances. But the opportunities for participating in this transformation are highly unequal. Availability of financial capital, ownership in assets (e.g., housing), social capital, education, and associated informational advantages all impact the possibilities of investment and technology uptake (Borenstein and Davis 2016; Kuhn and Schlattmann 2024). As the TCOs are lower for many electrotech products than for carbon equivalents, and as regulators increasingly reward flexibility, better resourced households gain economically over time and avoid carbon traps that poorer households increasingly fall into. Differences in socioeconomic resources partly (though not fully) correlate with differences in attitudes. The middle class endorses various kinds of investment (in education, real estate, etc.) as vehicles for status enhancement (Neckel 2018). Those left behind are likely to react with resentment and look to the future much more pessimistically, becoming receptive to counter-narratives that emphasize the worth and deservingness of a carbon lifestyle. In Germany, the controversy around the "heating law" – a regulation which tried to align households' investment choices with long-term climate policy pathways in the heating sector – exemplified such polarization and the importance of status questions in the transition (Wansleben and Terhorst 2025). In the British context, the scarcity of capital among many owner-occupiers has increasingly polarized climate policy and the energy transition (Edmondson, Kern, and Rogge 2019; Lockwood and Devenish 2024).

At the stage of advanced transitions, we thus enter into a period of conflicts in which new forms of energy generation and use, associated asset revaluations, and emerging imaginaries about the role of energy in society challenge status orders, understood as patterns of legitimate positions within a social space variously undergirded by carbon energy production, use, asset ownership, and "life forms" (Weber 1978). Status conflicts span economic sectors and the realm of private households. The threatened loss of status provides a more potent source of popular politicization than the sheer economic risk of asset losses. Strategies like those of Reform UK in the UK or the AfD in Germany can be made sense of in terms of these conflicts.

Institutional mismatches

Mismatch crises associated with renewable electrification also become manifest within and around the institutions and policies governing energy. We should think of the institutional crisis in advanced transitions not in terms of single policies or even "policy packages" (Edmondson, Kern, and Rogge 2019; Hoppmann, Huenteler, and Girod 2014) but at a deeper level. Institutional edifices are co-articulated with particular energy regimes and entail a plethora of specific rules concerning, for example, who builds and pays for grids, how energy prices are set, how standards are defined for generators and technology providers, how coordination is accomplished between generation, transmission, and demand, who is responsible for security of supply, and who enforces environmental protection. Both the depth of material and techno-economic transformation associated with VRE, as well as the breadth of such change, put profound pressures on such institutions. In all areas mentioned above, and many more besides, the rules associated with carbon/nuclear systems are ill-suited to a regime based on renewable power. At the same time, we have ample reason to think, following institutional theory, that institutional path dependencies and the obstacles to institutional reform will lead incumbent institutions to persist even if they become dysfunctional. For instance, institutions create beneficiaries, who simultaneously have significant veto power over reform options; institutions also entail complex distributional formulas that are extremely hard to disentangle (Offe 2004); moreover, they are deeply embedded in everyday practice by the coordinative functions of rules (Scott 2010); and institution building relies on collective action that is hard to come by, especially if those potentially taking such action (organized interest groups, trade unions, political parties) are weak. To the extent that reforms fail to happen, we observe situations of persistent institutional mismatch, which produce various pathologies. These mismatches manifest, in the first instance, in energy governance itself (grid planning and regulation, market design, energy welfarism) but also in higher level institutions.

Generalizing here for the countries under consideration, we can understand the problem of contemporary institutional mismatches by distinguishing roughly two periods of energy governance. In the first, from the late nineteenth century into the post-war period, institutions and policies were established to build large-scale fossil systems, sometimes complemented by hydropower. Monopolistic utilities together with the state drove this process of system building in most contexts, relying on large conglomerates to mobilize capital and "expert fraternities" to solve technical problems (Cohn 2017; Granovetter and McGuire 1998; Hausman, Hertner, and Wilkins 2008; Maier 2006; Schot and Lagendijk 2008). Subsequent projects around civil nuclear use were strongly state-driven (Hecht 1998; Uekötter 2022), while global private capital and decolonized oil-producing nations shaped transitions from coal to hydrocarbons (oil, gas) (Gross 2023; Högselius 2023).

A second phase, beginning in the 1980s in the United Kingdom, has been marked by liberalization (Bolton 2021; Christophers 2024). Power companies had to give up their monopolies, public ownership in many countries was abandoned, and grids and generation were separated, wholesale markets established, and regulatory oversight bodies introduced. In early renewables transitions, liberalization and expansions of VRE coincided. In some cases, a direct connection existed between one and the other. For example, in Texas, liberalization and the first green subsidies (renewable energy certificates) were introduced with the very same bill (Stokes 2020, 112). Moreover, unbundling broke the monopolistic power of large fossil and nuclear utilities and thus made grid access easier for renewable power generators, which wanted to feed into the grid but could not assume responsibility for stable uninterrupted supply, as the vertically integrated utilities had done. The more diffused ownership structure of renewable generation units aligned well with a switch from corporatist to more market-based coordination among increasingly numerous and heterogeneous participants. Moreover, because VRE production is weather-dependent, it first matched quite well with switching to a market model in which producers could sell power for fluctuating prices in ever more specific and shorter delivery intervals. Niche protection (subsidies such as feed-in tariffs or renewable energy certificates) complemented liberalized governance to drive renewable electrification forward and insulate an almost entirely "capex"-driven type of generation from markets primarily setting prices with "opex." Sometimes, this fragmented constellation of interventionist renewable support layered on top of liberalization created quite benign conditions for green developers, such as by allowing them to invest in distant locations without internalizing system costs (Newbery 2025), or by insulating renewables generators from the price drops and negative price phases that they themselves produced ("cannibalization").

It is thus important to recognize that we have now entered a new period, in which neither the old rules of fossil-nuclear system building, nor the liberalized frameworks of the past thirty years, provide adequate institutional foundations for renewable electrification. On the one hand, the "old" rules for carbon system building relied on relatively concentrated power, a strong emphasis on upstream coordination among producers (sometimes involving large industrial consumers), relatively cohesive elite networks, and the benefits of macroeconomic growth as well as increased welfare emerging from energy demand expansion; none of these conditions hold in the current era. On the other hand, liberalized governance plus subsidy policies offer insufficient capacities for solving the system building challenges, the coordinative demands, and the distributional conflicts associated with renewable electrification (Bolton 2021, 289; Valenzuela 2025).

For instance, *fiscal and financing institutions* are ill-equipped to support the necessary infrastructure overhaul (Gabor and Braun 2025), partly explaining the backlogs described above. These institutions constrain the overall volume of public funds available for infrastructure building. Fiscal policy is predominantly focused on annual cash disbursements and tax incomes, ignoring the impact of such budgetary decisions on the stock of public assets and welfare. Where rules open fiscal space for capital investments, decision makers often shy away from using these possibilities due to an ideological preference for private capital markets and a lack of public organizational capacities. This leaves as the main financing channel private capital remunerated via regulated user tariffs, which carries the risk of either disincentivizing private investments when regulated returns on capital are too low, or allowing excessive rents when the returns are set too high.[19] Current central banking reinforces these problems, for instance by disallowing interest rate discrimination in favor of investment in public infrastructure that could support renewable electrification. Tellingly, China as the country with the most dynamic renewable electrification eschews these restrictive fiscal-financial frameworks dominating in the West (Wang 2024).

A second institutional dysfunction is associated with *coordination* (Bolton and Poulter 2025, 15; Goedeking and Meckling 2024; Markard, Geels, and Raven 2020; Wansleben, Willems, and Golka 2026). It is clear by now that an energy system reliant on renewable electricity is extremely complex in its needs to link generation, transmission/distribution, storage/backup, and demand. Investment choices in the different system components have strong externalities – positive or negative. For instance, investment cases for transmission lines, batteries, the size/location of relevant generation units, and so on, change depending on the respective choices in the other components. In a stylized contrast, investors may envision a large (e.g., pan-European) supergrid favoring large (e.g., offshore wind) generation and large backup solutions; or they may expect smaller smart grids relying on flexible demand and location-specific solutions (for Denmark, this contrast is discussed in Blarke and Jenkins 2013; Hvelplund and Djørup 2020). A lack of coordination can increase costs for investors or provoke adverse selection. Current fragmentary policymaking, weak regulation, and market mechanisms in most contexts fail to solve these coordination problems. For instance, renewables support targets and market designs are often unaligned with system needs and fail to steer market participants towards making choices that serve the system; battery or wind farm investors install their equipment in locations that maximize their profits but do not minimize system costs. Market designs simultaneously produce "missing money" problems (Christophers 2024; Newbery et al. 2018) while also rendering energy expensive, by rewarding gas-fired power plants as the marginal providers of power in times of wind/sun scarcity. With insufficient coordination, uncertainties persist, misallocations become more like-

19 For the German context, Kölschbach Ortego, Gassen, and Steitz (2025) discuss these problems and recommend higher public equity participation in grid companies to reduce capital and ultimately grid costs for users. However, these opportunities are not pursued systematically in the current constrained fiscal, pro-capital markets framework.

ly, and the risk of frictions between different system components increases (Markard, Geels, and Raven 2020; Wansleben, Willems, and Golka 2026).

Third, current institutions are ill-adapted to deal with the *distributional conflicts* in advanced transitions. As described above, we see the buildup of significant distributional fault lines among social groups, which engage with the process of renewable electrification on highly unequal terms, tragically reinforced by various policies. Poorer households were already disproportionally affected by regressive funding modes for early renewables buildout, through instruments such as feed-in tariffs or grid charges. However, the distributional impacts of these fiscal instruments for financing renewable generation remained relatively small compared to the new pressures of fossil asset stranding and green tech investments that become salient in advanced transitions. In particular, large asset revaluation cycles (Colgan, Green, and Hale 2021; Green 2025) overtax current cost and benefit distributions established in early VRE expansion phases and under liberalization. Poorly targeted subsidies, early-mover support, and even seemingly progressive schemes like lump sum payments to households financed from carbon taxation fail to lift poorer households out of carbon traps (Neckel 2023; Wansleben and Terhorst 2025). Likewise, the kinds of green industrial policies currently adopted in countries like Germany are too fragmentary, short-term oriented, and responsive to incumbent interest group demands, leaving firms and workers poorly adapted to renewable electrification. According to the terms articulated above, (re-)distributive mechanisms thus are ill-suited to buffering the impacts of massive techno-economic change on status orders, undermining the legitimacy of the transition.

The intuition of institutional theory, as discussed above, is that path dependencies and the high hurdles for reforms lead to the persistence of status quo institutions or (if at all) only smaller, often insufficient reforms. As one example, demands for system-level planning as a way to solve the financing, coordination, and redistributive challenges of advanced transitions have been articulated not just by scholars (Ban and Hasselbalch 2025) but also by many practitioners in the energy sector itself. But existing planning attempts in Great Britain (around "Clean Power 2030") and Germany (around its "System Development Strategy") often remain timid and weakly legitimized (Wansleben, Willems, and Golka 2026). A second example of failed reform concerns ideas from economists and a few sectoral actors for radical marketization, in the shape of zonal pricing or stronger incentives for households to adapt to fluctuating prices and grid constraints (Özden-Schilling 2021; 2024). These neoliberal ideas have equally met with significant resistance in most contexts. For instance, economists oriented towards market solutions have advocated bidding zone reforms in Germany and Great Britain for several years now, but to little avail.[20] When dysfunctions translate into crises manifested in rising costs, losses of competitiveness, or infrastructure failures, political pressures increase.

20 An exception here may ironically be Texas, where the ideological dominance of free market ideas, the prominent role of economists, and pressure from large energy consumers have led to the adoption of relatively thorough market designs.

But given the various obstacles to institutional reform, these pressures are often channeled into adverse politicization rather than progressive problem-solving. As part of this, regulators and specialist policymakers face rising levels of distrust and institutional delegitimation. Rather than being put in the position to pursue the requisite reforms – in whatever direction is deemed suitable in a particular context – the institutional actors thus have extremely limited room for maneuver. This causes the institutional mismatch crises to grow.

4 Conclusion

Record renewable and electrotech deployment in times of unprecedented negative politicization and falling technology costs alongside rising system costs: These contradictory constellations, observed in advanced transition contexts such as Germany or the United Kingdom, call for new theoretical perspectives, as I have argued in this paper. These perspectives must speak directly to the frictions – infrastructural, socioeconomic, and political – that occur when renewable electrification penetrates ever more societal spheres, driven by climate policies but even more so by technological advancements. The existing conceptual toolbox of transition scholarship is ill-equipped to analyze these dynamics and to contribute to an encompassing understanding of the reforms that are needed to address current and future challenges. In this literature, there exists a weak conceptualization of transition dynamics beyond carbon lock-in and an overemphasis on positive feedback as technology- and policy-specific mechanisms to drive transitions forward. Instead, we must turn our attention to crises and conflicts around the support infrastructures needed for the transition; around distributional issues; and around more encompassing governance questions associated with a radically new energy regime, which have remained unresolved.

I have used the concept of mismatch or structural adjustment crises (Freeman and Perez 1988) to advance such an agenda. The simple intuition underlying this notion is that interconnected, multi-sectoral technological changes happen more quickly than the infrastructures, institutions, and socioeconomic status orders in societies can adapt. This results in extended structural adjustment crises, which are articulated in concrete social, economic, and political conflicts. I have conceptualized renewable electrification as a techno-economic paradigm change for the simple reason that it affords very different types of energy generation structures and ways of transporting and distributing energy and of pricing and using energy than we find in carbon societies; this also implies widespread changes in the production, distribution, and consumption of energy that affect almost all segments of society. In advanced transition contexts, these crises can be traced across infrastructures, status orders, and institutions. We encounter frictions in these constitutive ordering dimensions of carbon society and can identify how they lead to conflicts, often facilitating adverse politicization from anti-green groups.

Two objections can be made to the claims articulated in this paper. Some transition scholars may say that the idea of a regime- or system-level crisis brought about by technological innovations is inherent to existing theories, such as Geels' (2019) multilevel approach. This implies that the explicit theorization of structural adjustment crises delivers no new insight. I disagree with such a possible critique, for several reasons. First, the ways in which renewable electrification challenges carbon orders have remained underspecified in existing discussions; a focus on problems of technological innovation or "whole-of-system" transitions has suppressed a more serious engagement with the specific material, techno-economic, and sociocultural affordances of renewable electrification. Second, distinctions such as those between a regime and its landscape have obfuscated rather than rendered explicit the nexus between energy and sociopolitical order, thereby also downplaying the extent to which energy transitions provoke social change. Relatedly, despite the literature's talk of regimes, the constituents of carbon orders have remained undertheorized. By tracing structural adjustment crises across infrastructures, status orders, and institutions, I have addressed this gap. My approach also transcends an exclusive focus on specific interest group conflicts in political economy, which juxtaposes "brown" with "green" coalitions. Crises in advanced transition contexts can only be understood in terms of the destabilized, fractured (infra)structural and institutional terrains upon which overt, actor-level conflicts are being played out.

Another, more profound objection may be that I overemphasize the coherence and exogenous force of renewable electrification. After all, a look at the sources meeting global primary energy demand today will quickly reveal a strong and relatively stable dependence on carbon (Fressoz 2024). Moreover, EVs, to take just one example, may win over markets quite independently of other components of renewable electrification, like VRE, batteries, or heat pumps. Some domains, like cement or chemicals production, are so dependent on carbon that we cannot even see the beginnings of a transition. Moreover, carbon interests remain dominant globally and can still easily win any serious political battle. One may thus argue that the approach taken in this paper reads a lot into the recent successes of VRE buildout among a few climate policy frontrunners, plus the exponential adoption of electrotech over a few years (Walter, Butler-Sloss, and Bond 2025). My response to this objection is that the usefulness of analyzing mismatch crises does not depend on any consistent movement towards net zero: Progress is unequal across domains precisely because the depth of mismatch crises differs between them, and whether observable progress will lead to full decarbonization remains to be seen. But there is already sufficient empirical support that countries like Germany, Spain, the United Kingdom, or Denmark encounter mismatch crises at current levels of VRE penetration and electrification. While I *do* expect renewable electrification to continue and hence a further deepening of the respective crises, current conditions already render the conceptualization plausible.

Simply put, what I propose is to redirect attention from technology development problems and the policies needed to overcome them to the infrastructural supports, socioeconomic re-embedding, and institutional regulation required to stabilize a renewable energy-based order. Finding solutions to problems of infrastructuration, societal embedding, and regulation is a precondition for realizing the promise of renewable electrification as delivering a sustainable, secure, and affordable energy system for all. Current developments show that the success of such embedding is far from guaranteed even if progress in green technological development continues. There is a task here for sociologists to understand problems and perhaps even propose solutions. This work has only just begun.

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