

Power (re)distribution: How dominant capital regained control of the *Energiewende*

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Abstract The *Energiewende* (energy transition) is the dynamic and contested project of energy transition in Germany. It encompasses both the sociotechnical transformation of the German electricity system and the reorganization of the sector's ownership structure. In this paper, we present a Capital-as-Power (CasP) based analysis, investigating industrial path-dependency and innovation as part of the dialectics of power and sociotechnical change in capitalism. According to CasP, dominant capital seeks to increase its differential accumulation, i.e., accumulation relative to a benchmark. *Energiewende* policies initially decreased the differential accumulation of dominant electricity firms in Germany. However, we find that by concentrating their control over the shrinking conventional generation capacity, while variable generation expanded, dominant firms gained the leverage needed to increase differential prices and profits, thus managing to regain sectoral control by increasing their threat to reliable power supply. We find that these processes coincide with spatial centralization, ownership concentration, and decreasing penetration rates of renewable energy resources in Germany. By presenting new conceptual tools and empirical findings, we trace the ways in which the recovery of dominant capital in the German electricity sector shapes and restricts energy transition processes.

Keywords Energy transition · Power · Capitalism · Political economy · Electricity sector

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1 Introduction

“In the future, our focus will be on making generation capacity available when it is needed rather than just producing kilowatt hours ... I am optimistic that sooner or later we will receive adequate compensation for the security of supply that we provide.” *Rolf Martin Schmitz, RWE CEO (2016–2021)*

This quote by Rolf Martin Schmitz (then RWE CEO) appears in the company’s annual report for 2016 (RWE 2016, p. 5).¹ At the time, it seemed that Germany’s dominant electricity firms were facing a crisis. Following a decade of dominance (1998–2008), the ‘Big 4’ German electricity firms’ sectoral control seemed to decline (Kungl and Geels 2018).² The German *Energiewende* (energy transition), a project combining the sociotechnical transformation of the German electricity system with the reorganization of the sector’s ownership structure, had destabilized the electricity sector’s established business model. The business of electricity generation and supply had to be readjusted to accommodate subsidized renewable energy sources (RES) penetration and the decommissioning of conventional generation capacity, as well as to the associated impacts on grid stability by variable energy resources penetration.

Dominant firms had been steadily losing output share due to nuclear and coal decommissioning and had failed to invest in RES. However, in 2017, after a decade of declining profits and share prices (Kungl and Geels 2018), conventional and dominant electricity firms began showing steady signs of financial recovery. What could explain this reversal? How do sociotechnical changes in the electricity system influence the ownership structure and power relations in the sector? And how do those power shifts in turn influence the ways and means of transition?

This paper presents an empirical analysis of the interrelated processes of sociotechnical change and social power redistribution in energy transitions. We argue that energy transition is an open-ended process that can suffer reversals, whose pace and trajectory depend on power relations set in specific sociotechnical conditions. We will demonstrate how dominant firms find new ways through which to exploit the regulatory framework to their advantage and explore the effects of changing business models on transitional pathways.

Building on Capital as Power (CasP) theory (Bichler and Nitzan 2009), we develop and employ four conceptual tools for the empirical study of power in the transitioning German electricity sector. The tools combine techno-physical and pecuniary analysis to study the ways in which dominant firms attempt to leverage physical changes to increase their sectoral control, and the implications this might have for transition pathways. We contend that to understand social power in energy transition, we must study all three aspects of the business-industry-regulation triangle: using differential pecuniary data to represent business management, which is concerned with private profit; physical data to represent industrial changes; and

¹ RWE is one of the largest energy supply companies in Germany.

² ‘Big 4’ refers to RWE, E.ON, EnBW, and Vattenfall.

policy analysis to understand the regulatory framework through which public policy directs industrial change.

Data was collected for the years 2000–2022, to cover the period beginning with the passing of the first Renewable Energy Act (*Erneuerbare-Energien-Gesetz*, EEG 2000) until today. The conceptual tools integrate the analysis of financial and accounting records data, used to study business processes, with physical data, used to study industrial change.

We find evidence that, although at first unsuccessful, dominant firms have reasserted sectoral control by increasing their threat to reliable power supply, i.e., the potential impact of withholding conventional generation. The rising systemic dependence on shrinking conventional capacity provided dominant firms with the leverage needed to increase their differential prices and profits by enough to offset their loss of output share. Coinciding with these power processes we find increasing spatio-physical and ownership concentration trends in RES, alongside decreasing penetration rates.

The study makes a twofold contribution to the literature on energy transition: first, by developing conceptual tools for studying the dynamics of power and sociotechnical change in decarbonizing electricity sectors; and second, by using the case study of the *Energiewende* to empirically investigate dynamics of sociotechnical path-dependency and change as they relate to power redistribution in capitalism.

2 Energy transitions and social power

The study of social power in sociotechnical transition theory has gradually developed over the last two decades (Köhler et al. 2019).³ While initially used to explain regime resistance to change⁴, it now accounts for ways in which “regime-level actors may strategically engage in both restriction and promotion of innovation” (Levi and Israel 2024, p. 2), and in different expressions of agency and social power (Köhler et al. 2019). Institutional and policy studies have focused on the power of key stakeholders and interest coalitions to influence transition processes, while other research emphasized broad social conflicts, and struggles over energy justice issues (Becker and Naumann 2017; Leiren and Reimer 2018). Power has also been central to the study of policy formation processes. Renn and Marshall (2016) highlight the diversity of forces driving *Energiewende* policy formation, and the resulting paradoxes and unintended effects. They understand German energy policy to be propelled by protests, planning, contingency, and conflicts. Leiren and Reimer (2021) employ the multi-field framework to explain the shift toward greater competition in RES support in Germany. They argue that while both domestic organizational conditions and the European Union’s policy environment were influential in the

³ Sociotechnical system theory defines systems as encompassing a wide range of complex interactions between humans, institutions, and technologies (Morgunova 2021).

⁴ According to multi-level-perspective on sociotechnical transition, stabilization and transformation are driven by the “macro” landscape level, the “meso” regime level, the “micro” niche level, and the relations between them (Morgunova 2021).

process, it was the political field which was most decisive. They point to a political conflict which resulted in the gradual shift to more market-oriented policies (Leiren and Reimer 2021).

Another perspective on social power in energy transitions deploys the concept of *market power*, which refers to the ability of a firm, or group of firms, to set prices by manipulating supply, demand, or both (DePamphilis 2022). Most of these studies seek to uncover the so-called imperfect competition conditions prevalent in wholesale electricity markets. Thus, researchers have focused on the process of price formation in power exchange platforms. Pham (2019) suggests that the market power of dominant electricity generation firms might be exercised by physically withholding capacity, and/or by intentionally bidding prices up. Studying electricity markets in the USA, Borenstein et al. (1999) argued that during periods of high demand, dominant firms were able to strategically withhold supply to raise prices. They also expected that “extra-market sources of revenue—such as above-market contracts and capacity payments” would become increasingly prominent in the electricity market (Borenstein and Bushnell 2015, p. 26). While several studies have focused on the impact of RES penetration on the market power of conventional generators, Marshall et al. (2022) sought to study the potential of RES generators to exercise market power, stressing that the impact of RES penetration on grid stability and supply reliability may enhance this ability.

In energy transition literature, the concept of path-dependency has been used to address the ways in which fossil-fuel based sociotechnical systems reproduce themselves, creating various institutional, technological, and social “lock-ins” that complicate the process of decarbonization (Unruh 2000). Critics warn of an over-deterministic view of path-dependency and stress the need to better theorize the emergence of new industries under capitalism (Goldstein et al. 2023; Krafft et al. 2014).

Castoriadis (1984) offers an alternative way in which to understand the dynamic nature of innovation, arguing that under capitalism an abundance of technological innovation emerges, to the point of surplus. The selection between these creative potentials of production, the promotion of some techniques and the simultaneous repression of others, lie at the heart of the dynamics of power and resistance in capitalism. Thus, industrial path-dependency and innovation can be understood as part of the dialectics of power and sociotechnical change in capitalism. Change and inertia are shaped by power struggles that unfold within a given industrial terrain. Following this line of thought, the current study empirically explores the application of Capital as Power (CasP) theory to the analysis of energy transitions.

The CasP approach offers a theory of the ruling class,⁵ and the ways in which power is organized in modern capitalism.⁶ According to CasP theory, power is a dialectic social relation: it is always power over something and as such it creates its own opposition (Bichler and Nitzan 2020). In contrast to most orthodox and

⁵ A class comprised of ‘dominant capital’—firms and actors who achieve the highest levels of differential capitalization and retain the greatest effective power over social reproduction (Bichler and Nitzan 2009).

⁶ Capitalism in CasP theory is defined as a mode of power. A mode of power is the distinct structure of power relations and their reproduction within historical hierarchical societies (Bichler and Nitzan 2009).

heterodox conceptions of capital, CasP theory defines capital as a “symbolic representation of power” denominated in prices, rather than as a productive entity (Bichler and Nitzan 2009, p. 7). Capitalization is defined as the basic organizing algorithm of capitalism and differential accumulation as the goal of capitalist entities. In the following sections, we elaborate on these concepts and on the ways in which we integrate them into our study of energy transition in capitalism.

2.1 Capitalization

Capitalization is a mathematical algorithm—it discounts risk adjusted expected future earnings to present value. Capitalization acts as a measure of organized control exerted over the social process as a whole: politics, society, culture, and social reproduction (Bichler and Nitzan 2009). What is assessed and measured in capitalization is the broad social, rather than material, ability to generate income by shaping and controlling social processes. The capitalization formula is defined as follows:

$$K_t = \frac{E * H}{\delta * r_c} \quad (1)$$

where capitalization at a given time K_t equals expected future earnings (the product of actual earnings E and the hype coefficient H), divided by the product of the risk coefficient and the normal rate of return r_c . Thus, capitalization is based on four “elementary particles”: earnings, hype, risk, and the normal rate of return. Transitional changes, as they affect these variables, are figured into the capitalization process. In this sense, a CasP based analysis of power in energy transition goes further than a study of market power in that differential power accumulation is understood to be the goal of capitalist entities, and capitalization is understood to represent the degree of comprehensive exertion of power over the sociotechnical transition process.

2.2 Differential accumulation, breadth and depth

Differential accumulation is the driving logic behind capitalism. Capitalists are compelled to chase capital accumulation, yet accumulation as an absolute magnitude is meaningless. It acquires significance only when measured against a benchmark. Thus, it is the “difference between the growth rate of (one’s) own assets, and that of the average” that matters (Bichler and Nitzan 2002, p. 11).

Differential profit (the degree to which one’s profits exceed the average) is a central component of differential accumulation. We will present it in detail, as it will later support the conceptual tools used in the empirical analysis.

Bichler and Nitzan (2002) define profit as:

$$P = \text{breadth} \cdot \text{depth} = E \cdot P/E \quad (2)$$

where P is profit, and E is the number of employees, and P/E is profit per employee.

Profit is a consequence of both *depth* and *breadth*. *Breadth* refers to the size of the organization, i.e., the number of basic units controlled by the capitalist entity.

Depth refers to the elemental power of the organization, i.e., the earnings per unit of organization. Bichler and Nitzan use employees to represent the basic unit of organization, as they are concerned with the exercise of power by people over people (Bichler and Nitzan 2023). Capitalist organizations may accumulate by expanding in size, thus directly controlling more units of organization (breadth), or by extracting higher earnings per unit of organization, thus indirectly exerting power over society as a whole (depth), or by a combination of both.

Yet, as with accumulation, profit, breadth, and depth acquire meaning only in relation to the performance of others. Thus, differential breadth is defined as the strategic expansion in relative organizational size, and differential depth is the strategic increase of relative earnings per employee (Bichler and Nitzan 2009).

At any given moment in time, this can be expressed as:

$$DP = dif.breadth \cdot dif.depth = \frac{E_1}{E_2} \cdot \frac{P/E_1}{P/E_2} \quad (3)$$

here, DP is differential profit, $E1/E2$ is differential employment and $P/E1 / P/E2$ is differential profit per employee.

As will be presented in Sect. 4.2.1, we base our differential tariff tool on the concept of *depth* presented above. As depth processes are understood to increase the elemental power per ‘unit of organization’, the unit of analysis must align with the social field being researched. For example, James McMahan (2015) measures Hollywood’s differential depth as earnings per film. We use energy units as the relevant unit of organization for the study of a decarbonizing electricity sector.

2.3 Business-industry-regulation and strategic sabotage

The objective of differential accumulation is outperforming one’s opponents and “beating the average.” Thus, sabotaging production can become as instrumental to differential accumulation as production itself. Bichler and Nitzan define *strategic sabotage* as the ability to “restrict, limit and inhibit the autonomy of those with less or no power,” for the purpose of increasing profit (Bichler and Nitzan 2017, p. 2). This framing is based on Thorstein Veblen’s (1923) distinction between business and industry, according to which industry is a collective endeavour to systematize social production, drawing on the “technological heritage” of a society, which, when unrestricted, is held in common and shared across the whole society. Business, in contrast, is an institution of power solely concerned with profit and accumulation, i.e., with distribution. It lays claims to industrial processes, increasingly bringing industry under its control, substituting the collective enhancement of well-being with the sectorial quest for differential accumulation (Veblen 1923).

The state in CasP theory is seen as inseparable from capital. It is itself a capitalized entity in a dual sense: governmental bonds are a capitalization of the state’s power to tax and form the basis of global finance; and governmental action bears upon capital accumulation thus getting figured into capitalization (Bichler and Nitzan 2009).

This study pursues issues of path-dependency and change in decarbonizing electricity sectors from the perspective of capitalized power. Following the CasP frame-

work, social power is studied using differential pecuniary measures. Thus, we employ financial and accounting data, such as market capitalization and revenues from power generation, respectively, to construct differential measures representing changes in the distribution of power within the electricity sector as transition processes unfold. Physical data, like total net generation, is used to study industry-side changes.

Previous studies have made insightful contributions to understanding the wider social context of the *Energiewende* policy formation process (Renn and Marshall 2016), the impact of governmental political dynamics on it (Leiren and Reimer 2021), and the influence of the corporate capture of political parties by fossil-fuel based energy firms on energy transition pathways (Lucas 2021). We seek to contribute to these efforts by addressing the pervasive and diverse ways in which power is exerted upon energy transition processes through their capitalization. However, differential accumulation measures in and of themselves tell us little about the ways and means of power accumulation and exertion pertaining to specific sociotechnical processes. Therefore, we have developed conceptual tools for the study of capitalized power in transitioning electricity sectors.

3 The case of the *Energiewende* in the German electricity sector

In this section, we introduce our case study. The first part describes the *Energiewende*'s major features. The second discusses the main industry-side changes in the power sector, and their significance.

3.1 The German *Energiewende* and the electricity sector

The German federal government's *Energy Concept* sets environmental, economic, and social targets, to be achieved through the decarbonization of the energy system (Quitrow et al. 2016). *Energiewende* legislation and policies award a central role to the transition in the electricity system which is stipulated in the *Erneuerbare-Energien-Gesetz* (Renewable Energy Act, EEG 2000), article 7 of the *Atomgesetz* (German Atomic Energy Act, AtG § 7 1959), and the *Kohleverstromungsbeendigungsgesetz* (German Act to Reduce and End Coal-Fired Power Generation, KVVBG 2020). It entails increasing the share of RES in electricity consumption to 80% by 2050 while simultaneously phasing-out nuclear and coal-based power plants by 2023 and 2038, respectively.

The *Energiewende* initially supported strong citizen involvement in RES, with early trends showing high prosumer⁷ shares in newly installed RES capacity, and a growth in citizen-energy projects, although these have been in decline in recent years (Kahla et al. 2017). Moreover, dominant firms were late to invest in RES and,

⁷ The term prosumer is a compound of the words producer and consumer. In the field of electricity, it refers primarily to electricity consumers which also participate in electricity production, management, trade, and storage (Kotilainen 2020).

until recently, it seemed that their control of the sector was gravely destabilized (Kungl and Geels 2018).

3.1.1 *The Energiewende and electricity sector liberalization*

While it was the passing of the EEG 2000 that kick-started rapid RES penetration, the restructuring of the German electricity sector began earlier. In accordance with the EU's 96/92/EG directive, initial steps toward the liberalization of the German electricity sector were taken in 1998 (Müller et al. 2008). Germany's power sector preceding liberalization was dominated by privately-owned, vertically integrated, regulated monopolies. Liberalization implied the "unbundling" of the sector: its separation into generation, transmission, and distribution segments, and the creation of wholesale electricity markets (Joskow 2006). This liberalization of the utilities sector was not unique to Germany. During the 1990's, the electricity sectors of many countries underwent liberalization processes entailing such measures as the privatization of state-owned enterprises, the deregulation of the generation and retail segments, and electricity market construction (Joskow 2006). Liberalization was promoted as a means of reducing consumer prices, enhancing efficiency, and increasing RES penetration (Steffen et al. 2022). Nevertheless, a recent study indicates that in the EU, state-owned utilities show a higher tendency to invest in RES (Steffen et al. 2022).

3.1.2 *Major business-industry-regulation dynamics in the Energiewende*

The *Energiewende* from the outset, has been a conflictual process, shaped by decades-long social struggles. Despite Germany's relatively broad consensus over nuclear phase-out and RES capacity build-up (Leiren and Reimer 2018), exactly how climate policy should be implemented has been continually contested by citizens, policymakers, and industry stakeholders (Beveridge and Kern 2013). Struggles transpired over RES and phase-out policies, issues of energy-democracy and participation, local opposition to infrastructure development, electricity prices, and more (Paul 2018; Reuswigg et al. 2016).

In the wake of liberalization, the 'Big 4' electric utilities consolidated their power in both the German and European markets, while retaining full overview of the German market through their control of three of the four German transmission system operator firms (Kungl and Geels 2018). At first, dominant electricity firms in Germany were set back by the industry-side changes in the electricity system, and their related regulatory framework. Regulation mandated the limitation of production through nuclear and coal phase-out policies. Yet, while the transition away from nuclear power was initially imposed on them, dominant utilities used their power in negotiating the *Atomkonsensus* of 2000, which is an agreement between the government and electric utilities on the future of nuclear power in Germany. This agreement formed the basis for the 2002 amendment to the Nuclear Energy Act (AtG § 7 1959), which delineates the nuclear phase-out. Dominant utilities continued to contest phase-out policies and lobby against them. In 2009 their efforts

bore fruit and the CDU-led⁸ government halted the phase-out, extending the lifetime of nuclear power plants, despite strong public disapproval. However, following the Fukushima disaster in 2011, the very same government reversed this reversal, and the full decommissioning of nuclear capacity in Germany was completed in 2022. The coal exit, under the coal phase-out act (KVBG 2021), has proceeded to administer the full but gradual decommissioning of coal capacity by 2038. This enforced decommissioning of (still profitable) nuclear and coal installations significantly influenced the development of sociotechnical change (Rogge and Johnstone 2017).

Early Renewable Energy Act legislation (EEG 2000) mandated grid priority for RES, and guaranteed them above market price FinTs for a period of twenty years. This regulatory framework threatened to destabilize dominant firms, since they were simultaneously losing output share, gaining differentially lower returns per unit of electricity, facing increased competition, and failing to invest in RES, investing instead in new conventional capacity and costly take-overs (Kungl and Geels 2018). Dominant utilities had also failed in their attempt to push for the construction of a capacity market in the 2016 German electricity market reform. This reform was instigated in response to increasing variable energy resource penetration and concerns about security of supply. Instead of a capacity market mechanism, which would have secured broad and significant capacity payments for conventional generators, policy-makers opted for strengthening the energy-only market and constructing a strategic reserve with limited capacity payments (Gawel et al. 2022).

A major policy-related shift toward RES liberalization occurred in 2017. Strong business and institutional forces, both at the German and at the EU level, had been pushing back against the fixed FinT for RES generators, in favour of a “competition-oriented” approach. Addressing public discontent about the rising EEG costs and household electricity prices, whilst also saving conventional electricity generation firms from insolvency, a set of amendments to the EEG law were drawn in 2014, 2017 and 2023. These amendments have shifted RES policy from direct public subsidy to market-based mechanisms, such as an auctioning system for new RES capacity and compulsory direct marketing (Leiren and Reimer 2018). Even with built-in citizen-energy support mechanisms,⁹ the move strongly benefited large firms at the expense of smaller actors and citizen-energy (Leiren and Reimer 2018). While early FinT measures proved instrumental in instigating RES penetration and decentralization, market-led mechanisms clearly advantage big actors, changing the trajectory of transition (Morris 2019).

To conclude, the *Energiewende* is a relatively developed case of transition in the electricity sector; it includes significant RES penetration alongside the decommissioning of conventional capacity and the decentralization of generation, and the destabilization of established business models. Citizen-led struggles for energy democracy contest policy measures associated with an entrenched neoliberal mind-

⁸ The term CDU refers to the conservative Christian Democratic Union of Germany party.

⁹ This refers to the 2017 amendment of the EEG§ 36g “Special auctioning rules for citizens’ energy companies”, as well as to the entitlement of small installation operators to a FinT (up to 100kW).

set. Therefore, we find it highly suitable for the study of social power in energy transition research.

3.2 Variable energy resource penetration—understanding industry-side changes in the *Energiewende*

The *Energiewende* brought major changes to the electricity system. These include Variable Energy Resources (VER) and decentralized energy resources (DER) penetration, nuclear and fossil-fuel decommissioning, and their effects.

VER are typically also RES technologies. Power generation by VER is dependent on environmental conditions, and their output varies over time (Ambec and Crampes 2019). DER are less consistently defined, consisting of a diverse array of resources generally characterized by proximity to customers and provision of both electric power services and grid stabilization services, like demand management (Shen et al. 2021).

The degree of VER integration is often referred to as ‘penetration,’ denoting their share in a system’s energy mix. Variability, uncertainty, and non-synchronous generation¹⁰ are all characteristics of VER that adversely affect grid reliability and stability (Abido et al. 2020; Impram et al. 2020). Grid reliability is affected by the growing share of resources which cannot be dispatched on command, disrupting the ability of system operators to react to fluctuations in demand, particularly during peak load,¹¹ and to ensure universal and reliable supply of power. Moreover, grid operation requires an ongoing balancing of load with available generation capacity over different timescales (Fine et al. 2017). The displacement of dispatchable base load generators reduces system inertia, which complicates the maintenance of grid stability and may raise the potential for rolling blackouts, and more (Johnson et al. 2020).

As VER penetration increases, electricity systems rely increasingly on limited conventional capacity in times of low variable generation to sustain grid reliability. In the case of the *Energiewende*, not only does VER penetration increase, but conventional installed capacity is reduced through decommissioning. This implies that, *ceteris paribus*, reliable electricity supply during peak load is dependent on a decreasing conventional installed capacity. Research points to several systemic solutions to the challenge of maintaining grid reliability and stability with high RES penetration levels. These include the integration of various energy storage systems, like distributed battery storage and pumped hydro, and various grid management and control technologies, like synthetic inertia solutions and demand response (Alam et al. 2020; Jacobson et al. 2015). Yet, these solutions require planning, political will, and significant investment (Sopher 2015). Crucially, the adequacy of grid and energy storage development in Germany for accommodating RES penetration and decarbonization goals is questioned (Redeker 2024; Schwarz and Cai 2017). Thus,

¹⁰ Non-synchronous generators reduce the amount of rotational inertia available in a system. Consequently, grid stability decreases (Johnson et al. 2020).

¹¹ The highest electric power demand on a grid over a specified period.

Table 1 Sociotechnical categories in electricity generation

Category	Resource/Technology
Alternative Electricity Generation (AEG)	Onshore wind
	Offshore wind
	Solar PV
	Geothermal
	Biomass
	Waste
Conventional Electricity Generation (CEG)	Hard coal
	Lignite
	Natural Gas
	Nuclear
	Oil
	Mineral oil products
	Hydro

reliance on dispatchable power plants for security of supply has become central to conventional electricity generation firms' business model and argumentation.

4 Methodology

4.1 Power generation segment taxonomies and data sources

Our study focuses on the generation segment, for which the impact of decarbonization is the strongest.¹² The major sociotechnical changes in the German electricity system include subsidized VER penetration, and the decommissioning of fossil and nuclear fuelled generation. We assume that differential, rather than absolute, measures account for power dynamics. Consequently, we organize electricity generation into four categories, reflecting the major conflictual changes in the generation segment, and the restructuring of social relations therein.

As shown in Table 1, the first pair of categories differentiates alternative from conventional electricity generation, based on technology and resource-related characteristics. The categories were devised in accordance with major changes affecting sectoral structure. Thus, the significant sociotechnical features of Conventional Electricity Generation (CEG) include dispatchability and heritage, while for Alternative Electricity Generation (AEG), our focus is on variability and public subsidy.

In practice, different measures include slight variations in the division outlined in Table 1, due to data availability considerations. Nevertheless, the core assignment of variable energy resources (wind and solar) to AEG, and fossil fuels and nuclear to CEG, is contained in all the measurements (see Appendix 1).

The second pair of categories differentiates between dominant and non-dominant firms in electricity generation. Here too, the division is not as straightforward as it may at first seem. Prior to the liberalization of the German electricity market, the 'Big-4' dominant firms (RWE, E.ON, Vattenfall, EnBW) consolidated their control

¹² Whereas the transmission segment is also significantly affected by VER penetration, it remains regulated in Germany and thus is able to pass on costs to consumers and earn stable returns.

Table 2 Conventional Total Net Generation by the five largest German electricity producers 2020–21. (Source: BnetzA 2022, p. 50)

Germany 2020			Germany 2021		
Companies	TWh	Share	Companies	TWh	Share
Dominant 5	175.0	65.3%	Dominant 5	198.0	67.0%
Rest	92.8	34.7%	Rest	97.5	33.0%
Total	267.8	100%	Total	295.5	100%

Table 3 Conventional Installed capacity of the five largest German electricity producers 2020–21. (Source: BnetzA 2022, p. 52)

Germany 2020			Germany 2021		
Companies	GW	Share	Companies	GW	Share
Dominant 5	52.6	56.7%	Dominant 5	46.0	53.0%
Rest	40.4	43.3%	Rest	40.9	47.0%
Total	92.6	100%	Total	86.9	100%

over the sector and increased their market share in generation (90% of Total Net Generation in 2004) (Kungl and Geels 2018). However, as VER penetration developed, dominant firms lagged in building RES generation, whilst simultaneously instructed by the authorities to divest from certain assets and decommission nuclear and coal installed capacity, and started losing output share, profitability, and influence (Kungl 2015). Concurrently, a process of specialization began, with RWE and E.ON effectively splitting up the market between them, specializing in generation and supply, respectively (Berlo and Wagner 2020). The dominant/non-dominant division, however, is still significant to understanding power relations, especially with regard to conventional electricity generation. By ‘dominant firms’ we refer either to the three firms with the largest market share in electricity generation: RWE, LEAG, EnBW; or to the five largest, by including E.ON and Vattenfall (BnetzA 2022, pp. 49–52; Bundeskartellamt 2023). Table 2 (taken from BnetzA Monitoring Report 2022) shows that the dominant 5’s share in conventional Total Net Generation, though lower than during the first decade of the 21st century, is still significantly high (67% in 2021). Table 3 shows that dominant 5 firms’ share in conventional Total Net Nominal Generation Capacity remains over 50% in 2021, even following the significant decommissioning of nuclear capacity, which was solely held by dominant firms.¹³

For further details on the subsidiaries of dominant firms, see Appendix 1.

We will now focus on the data source types used to study power in sociotechnical transitions.

¹³ Conventional total net nominal capacity (Table 3) refers to the maximum electric output that all conventional power plants connected to the grid can produce under specific conditions. Conventional total net generation (Table 2) refers to the amount of electricity generated by all conventional power plants connected to the grid during a certain year, after deducting the electricity consumed in the plants’ operation. While the first is a measure of maximum generation potential, the latter is a measure of power generation.

Table 4 Data Classes, Categories and Corresponding Sources

Data Class	Data Category	Data Source
Accounting Records	Revenues from Power Generation by company size	DeStatis ¹
	Fuel Price for Electricity Generation	AGEB ²
	Export Revenue	BnetzA ³
	Import Costs	
	Total EEG Remuneration	
	Total EEG Remuneration	
Financial Data	Market Capitalization	COMPUSTAT
	Total Return Indices	Global ⁴ Eikon Refinitiv Datastream
Physical Data	Total net generation	BnetzA
	Total net nominal generation capacity	BMWK ⁵
	Annual Peak Hourly Load (ROITI 2023)	AGEB
	Conventional Peak Load	Statista ⁶
	Fuel Use in Electricity Generation	Fraunhofer ISE ⁷
	Electricity consumption	

¹Deutsche Statistische Bundesamt

²AG Energiebilanzen e. V.

³Bundesnetzagentur

⁴COMPUSTAT was accessed through Wharton Research Data Services

⁵Bundesministerium für Wirtschaft und Klimaschutz

⁶Statista was accessed through Tel Aviv University Libraries

⁷Data was retrieved from the Fraunhofer ISE site: <https://www.energy-charts.info/?l=de&c=DE>

We contend that to study power in sociotechnical transitions, we must study physical and pecuniary trends in relation to one another, and construct measures combining both data classes.

To study developments in the German generation segment, we use aggregate accounting records for electricity generation from the German Bureau of Statistics. An overall look at firms' performance is supplied by financial data, while physical data pertains to the analysis of generation installations.

Table 4 presents the three data classes used in the study.

For further details on data source by category, see Appendix 2. All data sets and R scripts used for this study are available on the project's page at Open Science Framework at https://osf.io/rhe5w/?view_only=5e50f54f97bf424abeb009a2eab2681b.

4.2 Conceptual tools for the study of power in a transitioning electricity sector

This section presents four measures which combine pecuniary and physical aspects of the transitioning system, through which the recovery of dominant CEG is studied.

4.2.1 The differential tariff

The differential tariff measure investigates the following question: how much do businesses receive for a unit of generated electricity? It has two forms: 1. revenue

per energy unit (€/MWh); 2. a rough proxy of gross profit per energy unit (€/MWh, taking into account average variable fuel costs).

This measure enables analysis of differential patterns, since it expresses the *depth* of accumulation based on energy units.

The electricity tariff is the price per unit of electricity. It can be expressed as:

$$\text{Electricity Tariff} = \frac{\text{total electricity generation revenue}}{\text{total net electricity generation}} \quad (4)$$

For the Conventional Electricity Tariff, we apply the same calculation, only this time using conventional electricity revenue and conventional electricity generation. These variables are calculated as follows:

1. *Conventional Generation Revenue* = Total Generation Revenue–Renewable Market Revenue
2. *Conventional Electricity Generation* = Total Net Generation–Renewable Generation

We use EEG market revenue (i.e., revenue obtained through sales on the market rather than subsidy payments) to express renewable market revenue, and EEG eligible¹⁴ electricity generation to express renewable generation.

Thus, the conventional electricity tariff (Eq. 5) is calculated as:

$$\text{Conv Tariff} = \frac{\text{convGR}}{\text{CEG}} = \frac{\text{TGR} - \text{EEGMR}}{\text{TNG} - \text{EEGEG}} \quad (5)$$

where *Conv Tariff* is Conventional Tariff (€/MWh), *convGR* is conventional generation revenue (million€), *CEG* is conventional energy generation (TWh), *TGR* is total generation revenue (million€), *EEGMR* is total EEG Market Revenue (million€), *TNG* is total net generation (TWh), and *EEGEG* is EEG eligible electricity generation (TWh).

By subtracting total EEG remuneration from total generation revenue, we obtain conventional generation revenue. Conventional energy generation is expressed as the difference between total net generation and EEG eligible generation. The quotient of the two results expresses the conventional tariff. For further details on how this measure is estimated within given data constraints, see Appendix 3.

The alternative electricity tariff (Eq. 6) is defined as:

$$\text{Alt Tariff} = \frac{\text{EEGR}}{\text{EEGEG}} \quad (6)$$

where *Alt Tariff* is Alternative Electricity Tariff, *EEGR* is total EEG Remuneration (million€) i.e., EEG market revenue + EEG subsidy payments, and *EEGEG* is EEG eligible electricity generation (TWh).

¹⁴ EEG eligible refers to electricity generation installations eligible for payment under the Renewable Energy Resource Act (EEG).

The gross profit proxy (Eq. 6) is estimated by subtracting fuel costs, which are a main variable cost component in electricity generation using fossil and nuclear fuels, from conventional generation revenue. For an explanation of how we calculate the measure and fuel costs, see Appendix 3.

4.2.2 Ratio of conventional installed capacity to peak load

The second measure is used to study the degree to which conventional electricity generation and dominant firms can threaten reliable electricity supply by withholding supply. As the ratio of conventional installed capacity to peak load decreases, there remains a smaller “capacity buffer” to uphold supply in case of low variable generation, particularly when coinciding with high demand. Thus, dominant firms’ potential threat to reliable electricity supply increases as the ratio decreases.

The measure of threat to reliable supply (Eq. 7) is defined as:

$$CIC/PL \text{ ratio} = \frac{CIC}{APHL} \quad (7)$$

where *CIC/PL* ratio is conventional installed capacity to peak load ratio, *CIC* is conventional installed capacity (GW), and *APHL* is annual peak hourly load (GW).

For additional related measures, see Appendix 3.

4.2.3 Ratio of total electricity sales to revenue from annual generation

Our third measure expresses the ratio of conventional generators revenue from total sales during a certain year (including forward contracts) to the sale of conventional power generated in the same year.

It is used to study the volume of forward contracts in electricity sales, and the degree to which these are used in comparison to spot market contracts. We argue that growing uncertainty about securing supply, due to decreasing conventional installed capacity and increasing VER penetration, may push buyers (retailers and industrial customers) to sign forward contracts, hedging against perceived future price rises, and enabling conventional generators to appropriate higher revenues.

The ratio of total sales to annual generation sales measure (Eq. 8) is defined as:

$$TES/AGR \text{ ratio} = \frac{TES}{AGR} \quad (8)$$

where *TES* is total electricity sales, including forwards (million€), and *AGR* is annual generation revenue, i.e., revenue from the sale of electricity generated during a certain year only (million€).

4.2.4 Conventional concentration

The final measure is an expression of the share of big firms’ revenue in the total revenue from conventional generation.

Due to data constraints, “big firms” are defined as having >250 employees, in accordance with DeStatis business registry’s criteria for the largest firms (a reasonable

proxy for dominant firms). The higher the share of big firms' revenue, the higher the concentration in conventional electricity generation.

The conventional concentration measure (Eq. 9) is defined as:

$$BFS = \frac{BFSR}{convGR} \quad (9)$$

where *BFS* is big firms' share, *BFSR* is total big firm sales revenue (million€), and *convGR* is conventional generation revenue (million€). For further information about this measure and its components, see Appendix 4.

5 Conventional recovery pathways: leveraging the threat to reliable power supply

In this section, we present and discuss the analysis results in four complementary parts.

5.1 Tracing conventional recovery

The following results first drew our attention to a change in the differential financial performance of German conventional electricity firms beginning in 2017. Our analysis is based on two Refinitiv Eikon Datastream indices: Germany Conventional Electricity and Germany Alternative Electricity. For further details on the indices, see Appendix 1.

Figure 1 shows the market capitalization of the two indices.

As is evident from Fig. 1, following the expected stagnation in conventional electricity market capitalization between the global financial crash of 2008 and 2016, the conventional market cap begins to steadily rise in 2017. Notably, this rise *precedes* the rise in the alternative market cap, which, after a short period of stagnation starting in 2016, is renewed only in 2019. Note that although the log scale shows the gap between conventional and alternative market cap shrinking rapidly, the German Conventional Electricity Index market cap is in fact still an order of magnitude larger than that of the German Alternative Electricity Index.

A broader financial measure, the Total Return Index (TRI), shows the same trend. Figure 2 shows the TRI of Datastream's Germany Conventional Electricity and Germany Alternative Electricity indices, as well as the DAX Performance index (DAX.PERFORMANCE), which acts as a benchmark and is based on the German stock market. The values are normalized to 2016, a year before the upward conventional trend begins.

As shown in Fig. 2, also in terms of total return, the conventional index begins to rise steadily in 2017, after a decade of stagnation and decline. The alternative index begins to rise again only in 2019. Finally, Fig. 3 shows that the same trends hold for net profit.

Note that in this graph, the rise in conventional net income appears to begin in 2016. This is due to the 3-year rolling average, used to smooth out the data, in which

Fig. 1 Germany Electricity Indices—Market capitalization

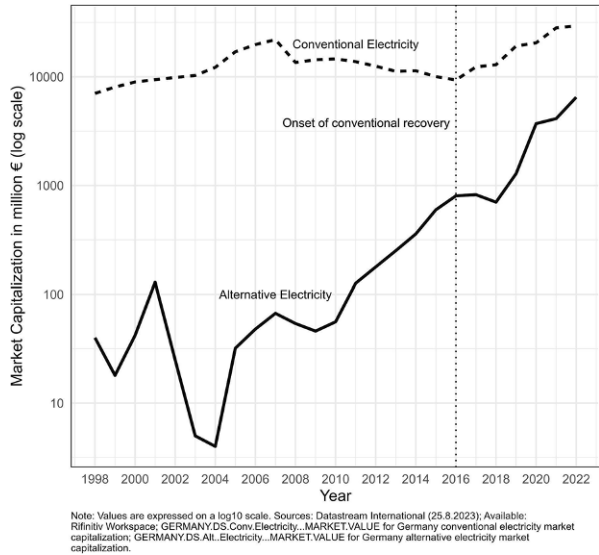
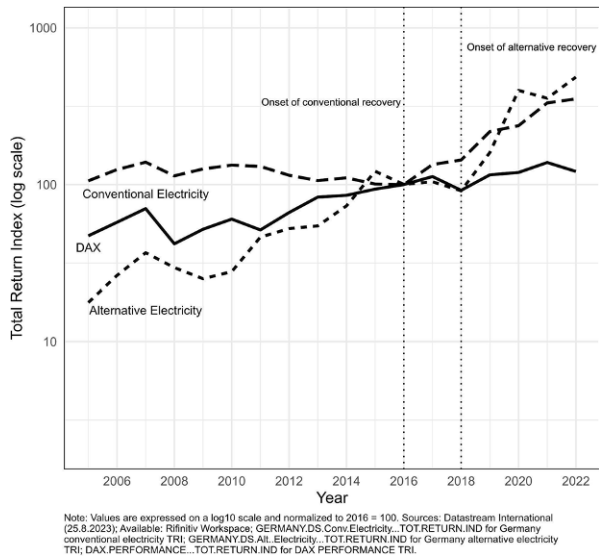


Fig. 2 DAX and Germany Electricity Indices—TRI (2016 = 100)



every datapoint expresses the average of the current, preceding, and following years. Alternative net income does not show a secular growth trend after 2016.

The apparent differential recovery of conventional electricity firms, and the growth in their differential income sent us looking deeper for its causes.

Fig. 3 Germany Electricity Indices—Net Income (3-year rolling average)



5.2 Uncovering differential depth

This part concerns the results of accounting records and physical data analysis. It is an analysis of differential accumulation, deriving Eqs. 4, 5 and 6 (see Sect. 4.2.1).

Figures 4 and 5 show the development of total revenue from annual generation (i.e. total revenue from the sale of electricity generated within the timespan of a year), total market revenue from annual conventional generation, and the share of market revenue from annual conventional generation in the revenue from total annual generation (%).

As Figs. 4 and 5 show, following a decade of decline, conventional market revenues begin to rise in 2018, concurrently with a steeper rise in total market revenue from annual generation. The same trend is displayed in the share of conventional market revenue, which rises from 31 to 42%, beginning in 2020.

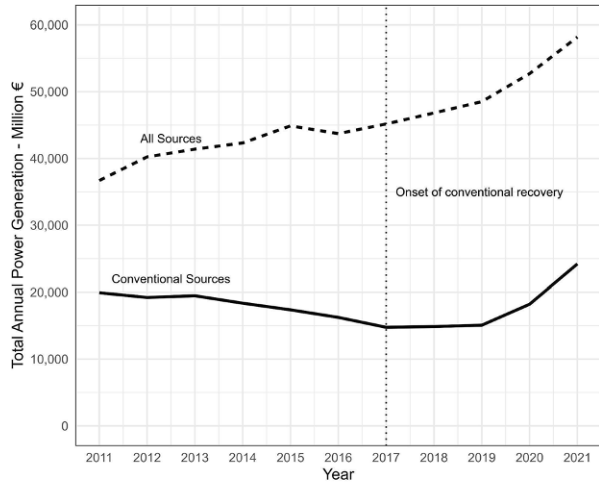
As seen in Figs. 6 and 7, during these years, CEG was consistently losing market share, as it kept decreasing in absolute and relative terms in favour of increased RES production.

Apparently, CEG firms were recovering **despite** accelerated output loss. We turned to differential depth measures to analyse the source of this recovery.

Figure 8 shows the results of conventional and alternative tariff analysis, based on Eqs. 5 and 6. It is an expression of revenue per energy unit.

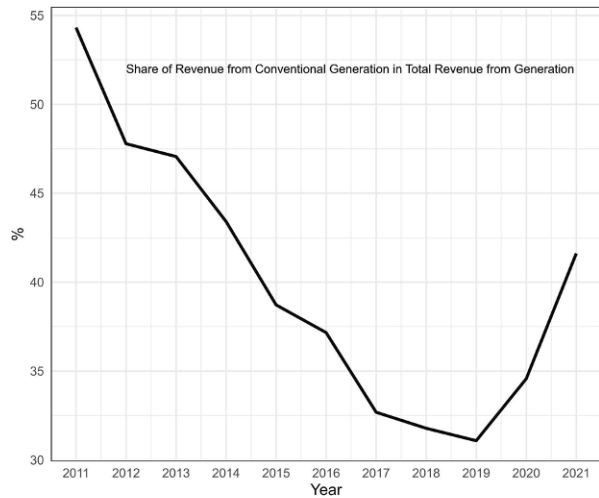
As can be seen, following a period of stagnation, revenue per conventional MWh began to rise in 2018, soaring in 2020, and reaching 70 €/MWh in 2021, 1.7 times the average conventional tariff for 2011–2018. Meanwhile, following a period of growth that lasted from 2006–2012 (2012 is 60% higher than 2006), the Alternative tariff began a secular decline, dropping from 177.5 €/MWh in 2012

Fig. 4 Revenue from Total Annual Generation and Annual Conventional Generation



Note: Total market revenue from annual generation and total revenue from conventional generation are approximations since separate data on the energy procurement component and the supply component were unavailable for all years. Sources: BMKW datasheet "EEG in Zahlen" for total EEG remuneration and its breakdown; AGE B datasheet "Stromverbrauch nach Kundengruppen" for non-household and household electricity consumption. For an explanation on how the average non-household energy procurement and supply component was estimated see Appendix 3.

Fig. 5 Share of revenue from conventional generation in the revenue from total generation



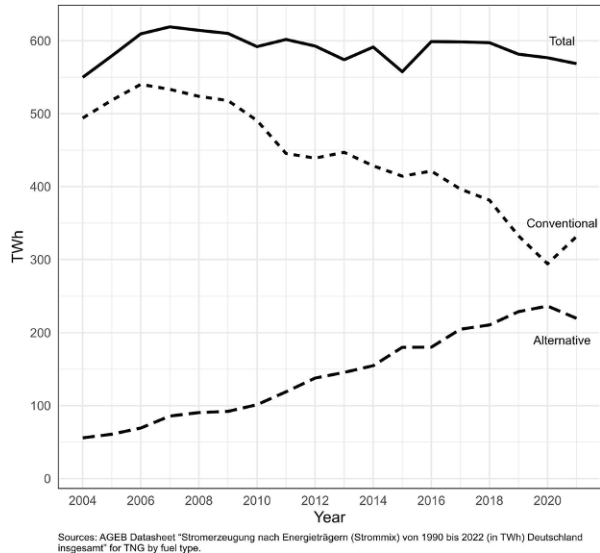
Sources: see Figure 4.

to 148.8€/MWh in 2021.¹⁵ This finding implies that, despite losing differential breadth, CEG firms succeeded in increasing their differential depth (price per energy unit) to a degree overriding their loss of output share.

Figure 9 presents profit per generation, based on Eq. 7. This figure shows that even when subtracting fuel costs, the trend remains similar. The rising conventional

¹⁵ The alternative tariff reflects market revenue as well as subsidy revenue, so that its level is considerably higher than the conventional tariff.

Fig. 6 Total Net Generation by generation category



tariff is not a case of “cost pushing” due to fuel price rises. Rather, CEG firms succeeded in sustaining high profit margins despite fuel cost fluctuations.

The results indicate rising differential depth in favour of CEG firms. This finding set us off researching the mechanisms behind it.¹⁶

5.3 Conventional concentration

This section showcases the results of accounting records analysis, based on the conventional concentration tool—Eq. 9 (see Sect. 4.2.4).

Up to this point, our findings traced CEG and AEG dynamics. But what of the relations between dominant and non-dominant actors?

Figure 10 shows the share of big firms’ revenue in total electricity sales, alongside the share of CEG in total electricity sales. We consider the ‘big firm’ category as a reasonable proxy for dominant firms’ revenue trends in the generation segment (see Appendix 4).

While big firms and CEG shares of total electricity sales generally display a similar trend, they tend to approach each other over the examined period. Even more importantly, in 2017–21, when both shares in total sales begin to rise, their levels completely converge. This finding implies that although dominant firms’ share of the generation segment declined, as nuclear and coal capacity (which they dominate) were decommissioned, beginning in 2017 they succeeded in concentrating conventional sales in their hands. This concentrated ownership group stands behind the

¹⁶ To our knowledge, this is a novel finding. Most analyses of prices in the German generation segment are based on wholesale power exchange data, which aggregates transaction values regardless of source, and only in part (omitting over-the-counter trading). Breaking down this aggregated market front exposed a recent and ongoing differential depth process.

conventional differential depth process starting in 2018 and is the main beneficiary of it.

5.4 Revealing the sabotage mechanism

In this last part, we provide a physical and accounting-records analysis, the first combining data from annual peak hourly load (APHL) and Conventional Electricity Generation (CEG), while the second examines total electricity sales in relation to annual CEG revenue. Specifically, we look at the ratio of conventional installed capacity to APHL, and the ratio of total electricity sales to revenue from annual CEG (Eqs. 7 and 8, Sect. 4.2.2–3). This approach, we claim, sheds light on the power mechanism behind the recovery of dominant CEG firms. Note that conventional generation market revenue includes only revenue from the sale of electricity generated during a respective year, while total electricity sales include forward contracts.

Figures 11 and 12 show the decrease in Conventional Installed Capacity, and its share of the Total Net Installed Nominal Generation Capacity (total net installed generation capacity). In 2017, for the first time, the share of conventional installed capacity in the total net installed capacity fell below 50%.

The following figures relate to decreasing conventional installed capacity in the context of securing a reliable electricity supply.

APHL is central to understanding grid reliability, as it sets the maximum energy demand a grid must support by all available generators.

As shown in Fig. 13, APHL in Germany has remained relatively stable at about 83 GW in recent years.

Figure 14 shows the ratio of Conventional Installed Capacity to APHL. The ratio begins to decline in 2017, even going below 1 in 2021.¹⁷ Most importantly, this trend anticipates the level of the conventional tariff: a reduced capacity reserve ‘predicts’ a higher price level in the short term.¹⁸ This implies that the reduced capacity buffer enables conventional firms greater leverage to increase prices and extract profits. Combined with a growing concentration in the conventional generation segment, these findings indicate an improved ability of dominant firms to coordinate and restrict electricity generation in general.

Note that although conventional generators’ share in total net generation has declined, their installed capacity is still critical to ensuring reliable supply (see Appendix 3).

The physical data analysis relates even more closely to differential depth, when examined by Eq. 8 (see Sect. 4.2.3).

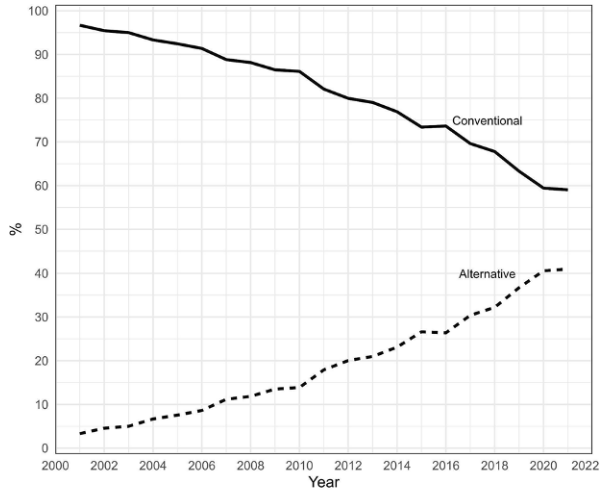
Figures 15 and 16 show the development of Total Electricity Sales, revenue from annual electricity generation and their ratio.

As shown in Figs. 15 and 16, the relative magnitudes of conventional total electricity sales and CEG market revenue change dramatically over time. While CEG market revenue displays a 63% rise between 2017–21, conventional total electricity

¹⁷ A similar trend of diminishing capacity reserve appears also for non-variable generation in total.

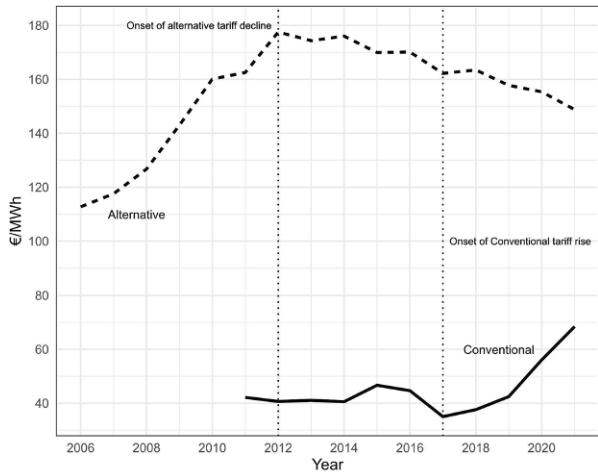
¹⁸ To illustrate, compare decline in Conventional installed capacity/Annual peak hourly load ratio beginning in 2016 (Fig. 14) to incline in profit per CEG beginning in 2018 (Fig. 9).

Fig. 7 Shares in Total Net Generation by generation category



Sources: see Figure 6.

Fig. 8 Conventional and Alternative Revenue per Unit of Energy Generation



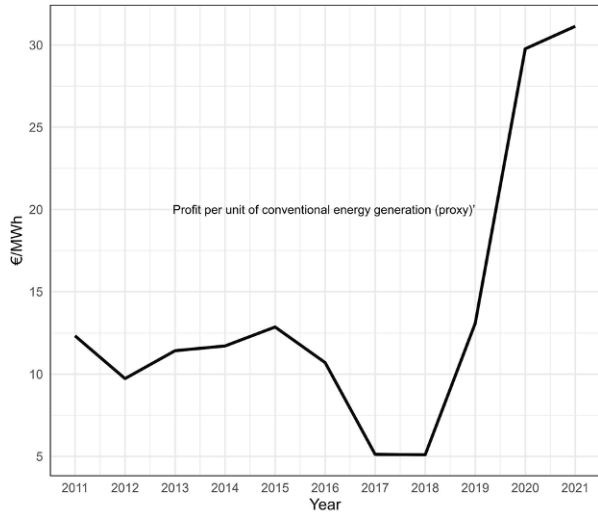
Note: Calculations are based on the conventional and alternative tariff tools presented in section 4.b. Please note that generation market revenue is an approximation, as separate data on the energy procurement component and the supply component were unavailable for all years. Sources: BMWK datasheet "EEG in Zahlen" for Total EEG remuneration and its breakdown and EEG eligible TNG/AGEB datasheet "Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2022 (in TWh) Deutschland insgesamt" For TNG; AGEB datasheet "Stromverbrauch nach Kundengruppen" for non-household and household electricity consumption; for an explanation on how the average non-household energy procurement component was estimated see appendix 3.

sales soars by 130%. In 2021, conventional total electricity sales are 5.5 times higher than CEG market revenue. As shown in Fig. 17, the ratio movements are parallel to those of the changing Conventional Installed Capacity/Peak Annual Hourly Load ratio: as the latter fell, the revenue ratio rose to a higher level.

Appendix 6 demonstrates the similarities between the Total Electricity Sales/Conventional Electricity Generation revenue ratio trends and average EEX Year Future¹⁹ price development trends.

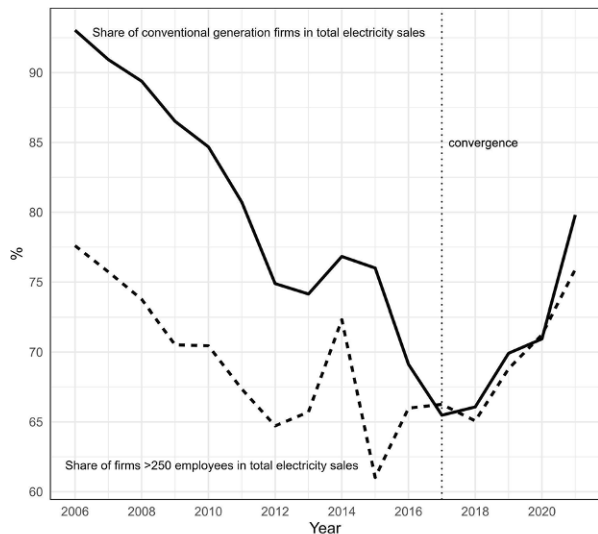
¹⁹ The European Energy Exchange (EEX) is a central European electric power exchange located in Leipzig, Germany.

Fig. 9 Profit per Unit of Conventional Energy Generation (proxy)



Note: Calculations are based on the Profit per Energy tool presented in section 4.b. Sources: BMWK datashet "EEG in Zahlen" for Total EEG remuneration and its breakdown and EEG eligible TNG; AGEB datashet "Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2022 (in TWh) Deutschland insgesamt" For TNG; AGEB datashet "Stromverbrauch nach Kundengruppen" for non-household and household electricity consumption; for an explanation on how the average non-household energy procurement and supply component was estimated see appendix 3. BDEW datashet "enpr.xlsx" for fuel prices in electricity generation; AGEB datashet "Auswertungstabellen zur Energiebilanz 1990 bis 2021" for fuel use in electricity generation.

Fig. 10 Share of Conventional Electricity Generation and Big Firms in Total Electricity Sales



Note: Total electricity sales refers to all revenue from electricity-generation-related business activity, including forwards and futures which are recorded on income statements. Data for big firms' revenue was missing in 2015-17. For details on how we estimated these two values see appendix 5. Sources: DeStatis data series "Destatis_740199_E12_URS_RE_Abschnitt_E_4Steller_BJ06-21" for total sales from electricity generation (Elektrizitätserzeugung) by company size 2006-2021.

These findings reveal the mechanism behind the rising conventional tariff, and the rising differential depth of conventional and dominant firms.

A growing uncertainty of supply (declining conventional capacity, increasing variable energy resource penetration) amplified dominant firms' effective threat to "hold back supply", especially during peak load. These conditions pushed buyers (retailers as well as industrial customers) to sign forward contracts, hedging against

Fig. 11 Conventional and alternative installed capacity

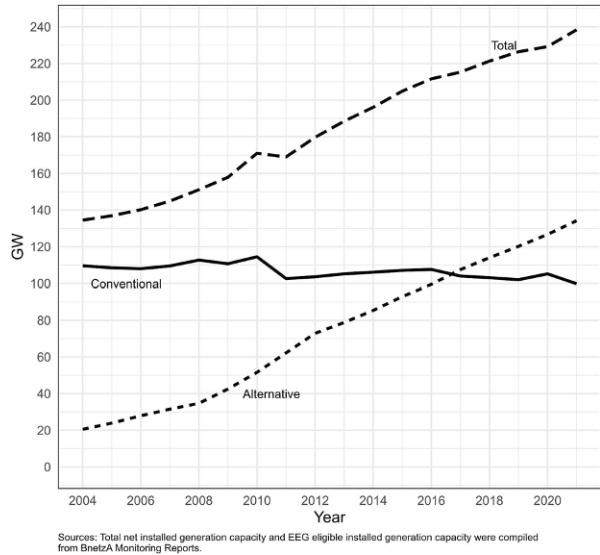
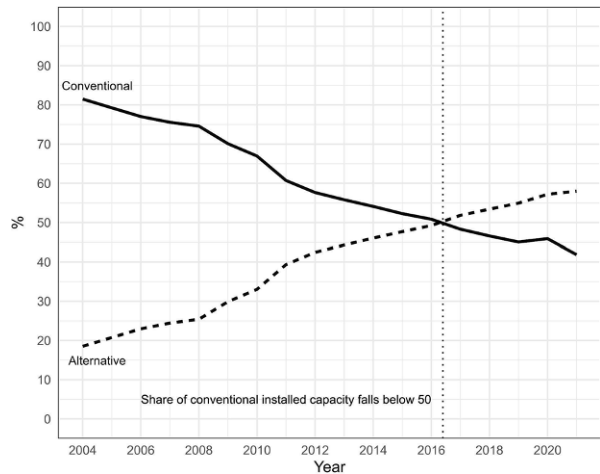


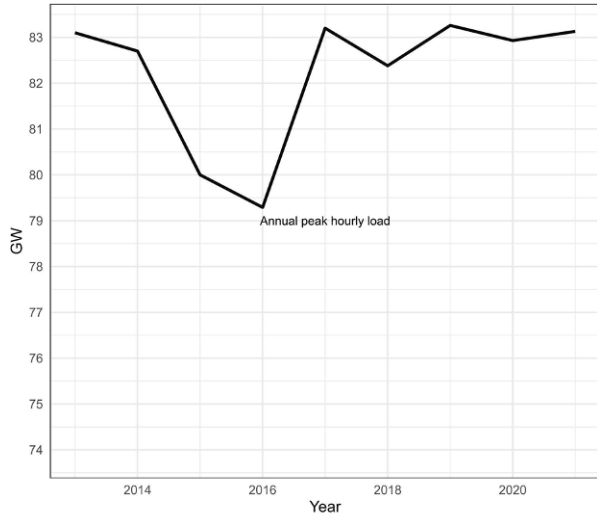
Fig. 12 Share of conventional and alternative installed capacity in total net installed capacity. (Sources: see Fig. 11)



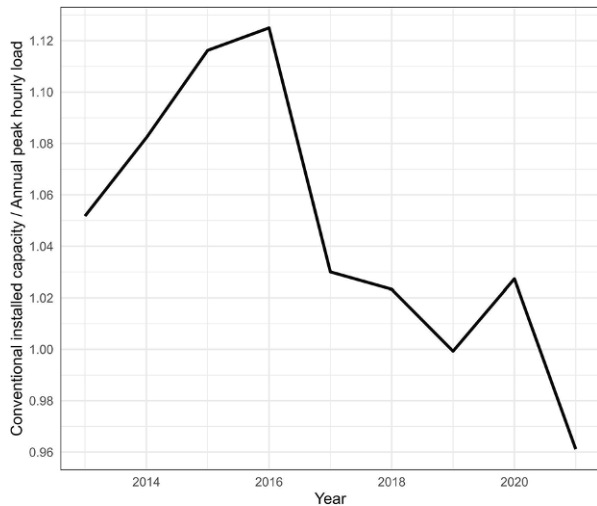
perceived future price hikes, and enabling conventional generators to appropriate higher revenues. This manifested in a rising conventional tariff, and a growing income share for dominant firms.

Thus, despite the initial set back, dominant capital has reasserted sectoral control by increasing its threat to reliable power supply. Concentrating their control over the shrinking conventional generation capacity, while variable energy resource penetration expanded, provided dominant firms with the leverage needed to increase differential prices and profits.

To conclude, these findings support the claim that dominant capital has reasserted sectoral control by increasing its threat to reliable electricity supply.

Fig. 13 Annual Peak Hourly Load

Source: Annual peak hourly load for Germany (monthly data, 2016-2023) was retrieved from Statista <https://www.statista.com/statistics/1342214/peak-hourly-electricity-load-germany-by-month/>. Accessed: 30.9.2023

Fig. 14 Ratio of Conventional Installed Capacity to Annual Peak Hourly Load

Note: Conventional installed capacity refers to fossil-fuel and nuclear capacity. Sources: Annual peak hourly load for Germany (monthly data, 2016-2023) was retrieved from Statista <https://www.statista.com/statistics/1342214/peak-hourly-electricity-load-germany-by-month/> accessed: 30.9.2023; data on installed conventional capacity was compiled from BNetzA monitoring reports 2013-2022.

The differential financial recovery of CEG firms began in 2017 (Figs. 1, 2 and 3). This recovery was possible *despite* CEG output loss (Figs. 6 and 7), by increasing differential depth, which manifested in the rising conventional tariff (Figs. 4, 5, 8 and 9). The rise in conventional tariff began in 2018 and coincided with a decline in the Conventional Installed Capacity/Annual Peak Hourly Load ratio (Fig. 14) due to processes of conventional decommissioning (Figs. 11 and 12), which preceded it by a year. We claim that CEG firms leveraged the reduced capacity buffer to increase prices and extract profits. This claim is supported by the findings presented

Fig. 15 Total Electricity Sales and Annual Electricity Generation Revenue

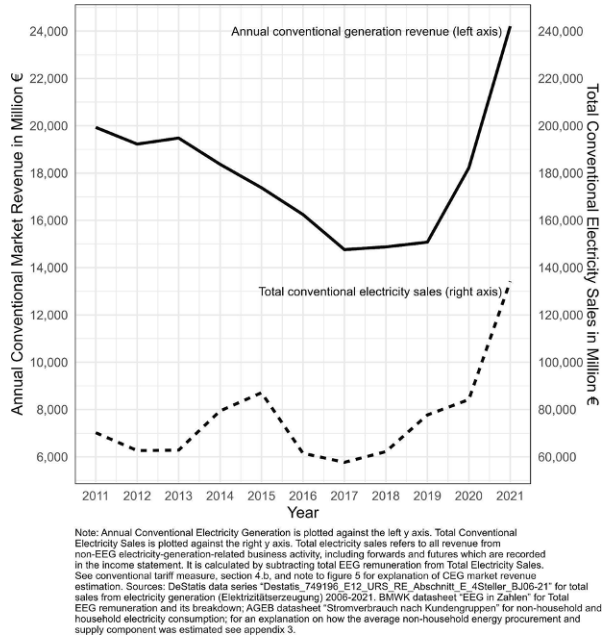
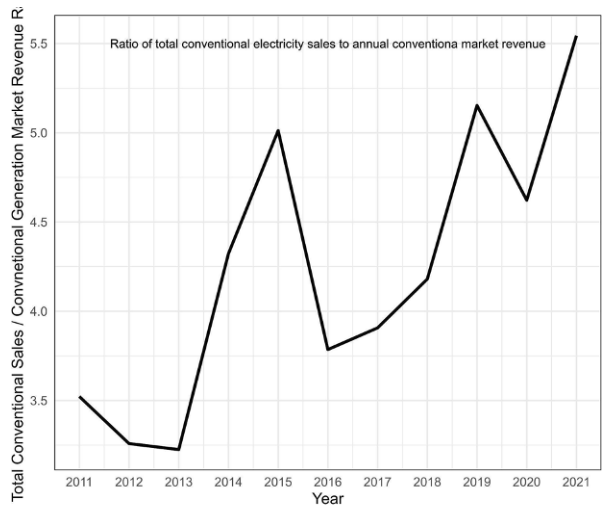
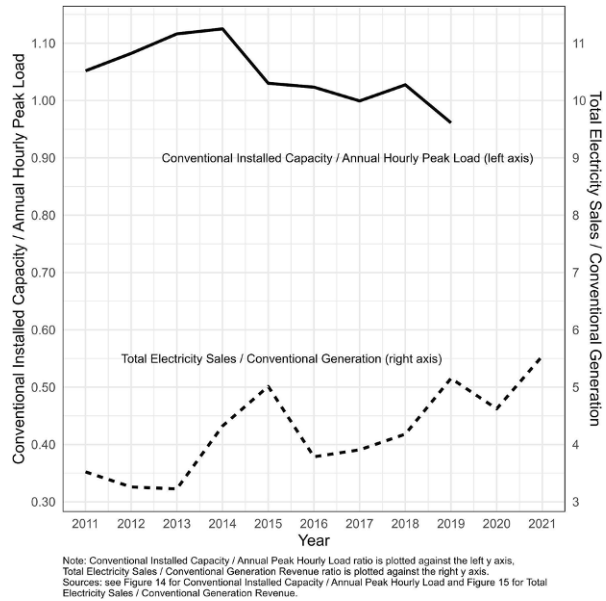


Fig. 16 Total Electricity Sales and Annual Electricity Generation Revenue Ratio



in Figs. 15, 16 and 17, which indicate that a growing share of CEG revenue can be attributed to the sale of forward contracts. Anticipating a growing uncertainty of supply, customers are pushed to hedge against future price hikes, enabling CEG firms to appropriate higher revenues. The main beneficiaries are big CEG firms, who succeeded in concentrating CEG sales into their hands (Fig. 10).

Fig. 17 Comparison of Conventional Installed Capacity/ Peak Annual Hourly Load ratio and Total Electricity Sales/ Conventional Generation Revenue ratio trends



6 Business-industry-regulation dynamics and energy transition pathways

The previous section presented and discussed the results of our empirical analysis of dominant electricity firms' differential recovery. Business, industry, and regulation are inseparable from one another in the power processes we uncovered. Moreover, the dialectical relations between techno-physical change and organized power have constantly shaped the energy transition. These dialectics are evident in the effects of the rapid and significant decarbonization of the electricity system in Germany on dominant firms in the sector, and in the ways in which the actions, reactions, and inaction of organized power in the sector affect transitional pathways.

As we have shown, although the restriction of conventional production was dictated rather than intentional, and although their initial lobbying efforts were unsuccessful, dominant electricity firms have found a way to exploit the regulatory framework to their advantage. The mechanism leverages the increased risk to reliable electricity supply due to VER penetration and conventional capacity decommissioning.

We describe this as sabotage, since income is extracted not from production itself, but rather from its control, backed by the threat of withholding generation.

Similar processes, like the re-emergence of coal in the context of high VER generation, and the incentive to secure electricity supply using forward contracts ("contract cover"), have been identified in the UK (Atherton et al. 2023) and in Australia (Rai and Nunn 2020), respectively.

Indeed, as these sabotage dynamics unfold, RES development displays increasing spatio-physical and ownership concentration trends, alongside decreasing penetration rates (see Appendix 7).

The double centralization of RES is accompanied by a declining alternative electricity tariff and a general policy push toward market-based mechanisms. This move away from direct public subsidy makes RES development increasingly dependent on, and susceptible to, “market forces.” RES projects’ return on investment depends more and more on market prices, and those are increasingly shaped in favour of conventional generation control. For example, the move from the FinT to a market premium mechanism means that EEG eligible generation is compensated for the difference between a regulated ‘value to be applied’ and an averaged market spot price. If RES’ sales prices trail behind the average price, they suffer an income loss. Moreover, the market-exposed regulatory framework can be expected to promote centralization, as small actors, cooperatives, and citizen energy projects might be disadvantaged compared to big ownership formations controlling RES (Morris 2019; WWEA 2019). The latter can strong-arm their way through market complexity and business risk.²⁰ Thus, the *Energiewende* project becomes intertwined with dominant capital, as it reshapes the electricity sector. Our study only hints at an associated trend relating to this growing convergence. The exact processes connecting spatio-physical centralization and power concentration are yet to be explored.

Arguably, business-regulation relations, or the state’s capitalized logic, have been pivotal to dominant firms’ current recovery. While dominant electric utility firms were at first unsuccessful in their attempt to block and overturn *Energiewende* processes, they have secured a central position in determining their conditions. Having made the project “their own,” they engage in reshaping it to their differential advantage, in a manner that affects the sociotechnical features of decarbonization, i.e., the centralization rate, ownership structure, and democratization of electricity generation. Moreover, the neoclassical logic which leads the increasing liberalization of RES penetration is embedded in national and supranational regulatory frameworks like those in Germany and the European Union. Consequently, although the FinT mechanism was a longstanding and central component of the *Energiewende*, the move to the auction system was “the result of a path-dependent process of incremental changes towards greater market-orientation” (Leiren and Reimer 2021, p. 96).

The results demonstrate the interrelatedness of sociotechnical change and organized power in Germany’s energy transition. While transitional processes affect organized power, and might destabilise established state-capital formations, these processes are not deterministic, and they may be reversed as dominant formations reorganize and reorientate themselves. This reorganization occurs in the context of specific industrial conditions. Industry, or more specifically, large sociotechnical systems, contains both path-dependent and innovative aspects.

The strong path-dependency of large and essential sociotechnical systems coincides with a constant flow of diverse sociotechnical innovation. Organized power might leverage both aspects of industry during transition, choosing to promote or

²⁰ Even dominant utilities might find themselves ousted from high-profitability areas such as offshore wind by bigger actors. This has recently occurred in the auctions for offshore wind capacity in the North Sea. 0-cent bids effectively turn the auctions to real-estate auctions, where the highest bid for the area wins. Thus BP and TotalEnergies could easily outbid all other participants (Amelang 2023).

discard new technologies, betting on reproduction or on change. In this sense dominant capital should not necessarily be viewed as materially entrenched in a specific technological setup, but rather as acting upon an industrial terrain in which path-dependency might prove as profitable as innovation.

7 Conclusion

This paper presents a CasP analysis of the means and consequences of power redistribution in a transitioning electricity sector. We developed and employed new conceptual tools for the study of differential depth, and its relation to spatio-physical changes in electricity generation and supply.

It appears that the “adequate compensation,” of which former RWE CEO Rolf Martin Schmitz was so optimistic, arrived sooner rather than later. Following an initial destabilization, dominant electricity firms in Germany derived a mechanism through which to regain sectoral control, for the time being. The mechanism relies on the strategic control of shrinking conventional capacity necessary for securing reliable supply. Schmitz himself put it simply: the point is making available (read: controlling) “generation capacity when it is needed rather than just producing kilowatt hours” (RWE 2016, p. 5). Why do dominant firms continue to rely on allegedly “obsolete” energy resources and technologies? We contend that the answer partially lies in the techno-physical features of the majority of RES, namely variability and uncertainty. The study’s findings demonstrate the significance of generation *control*,²¹ rather than output quantity, to differential profits. Variable electricity generation is, by definition, harder to control, so it requires tighter industrial coordination and regulation. Indicative of this is the EEG legislation that mandates the sale of RES electricity, making ‘withholding’ irrelevant. Given this business disadvantage of RES, and even with the prospect of a complete coal exit by 2038, dominant firms may find it profitable to continue “betting on coal.”

Ultimately, it is the public who pays the price for dominant capital’s differential gain. This is true in the sense that sabotage-induced price hikes are rolled on to consumers, as well as in terms of the broader implications of the capitalization of *Energiewende* policies. Arguably, the regaining of control over the electricity segment by dominant firms, coupled with the regulatory shift toward market mechanisms, is already becoming evident in the *Energiewende*’s trajectory: RES development, which initially displayed strong civic participation, is becoming increasingly socially and spatially centralized as it is being subjugated to “the market,” where the power of dominant capital has reasserted conventional generation as a superior business choice.

A major insight this study offers is that electricity exchange prices alone are often useless in the study of dominant capital. As a major share of electricity trading

²¹ Generation control involves the ability to manage the timing, quantity, and quality of generation output.

is done via over-the-counter contracts,²² exchange prices cannot be used alone to study differential patterns. To this end, we used aggregate accounting records, which revealed a hidden process of price formation. In our opinion, the missing public information on the sector, which conditioned the current research trajectory, is part and parcel of the power relations being researched.

This study is only an initial exploration of the dynamics of organized power and sociotechnical change in energy transitions. The findings call for further investigation into the specifics of differential extraction measures. Through what mechanism do dominant firms appropriated rising shares of conventional revenue?²³ How does the rising conventional-based power affect decarbonization pathways in the long run? How does centralization affect energy justice issues? These questions are of major *public* importance, as they relate to the ways, means and reasoning behind energy transition, perhaps the greatest sociotechnical challenge humanity faces.

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²² According to BnetzA's SMARD platform, "trading on the electricity exchanges only makes up around 20% of the total trading volume". And yet: "the electricity prices on the exchange are regarded as an indicator for the general wholesale prices" (BnetzA 2023).

²³ Was it mergers and acquisitions that led the way? differential pricing within the conventional segment? Data limitations prevent us from a definitive answer, for the time being.

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