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ARTICLE

Next stop carbon dioxide removal? German climate policies and the risky road to negative emission technologies

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Abstract Both the global and the German climate targets are ambitious given recent emission reduction rates. In addition to emission reduction measures, carbon dioxide removal has been increasingly discussed recently and initial measures have been developed to potentially scale-up carbon removals in order to meet net zero targets. In this article, we undertake a political economy-based analysis of the historical development and structural conditions of German climate policy measures and their enabling role for the emergence and strengthening of carbon dioxide removal policy options. We refer to regulation theory and the *Modell Deutschland* approach and argue that within this model the concept of ecological modernization has been established as the dominant approach to regulate society-nature relations. In light of the ambitious climate policy goals, such as net zero by 2045, ecological modernization reaches its current limits and must be recalibrated. Against this background, we conclude by discussing the risk of mitigation deterrence associated with carbon dioxide removals and considering alternative pathways, such as degrowth, to social ecological transformation.

Keywords Carbon dioxide removal · Climate policy · Ecological modernization · Economic growth · Mitigation deterrence · Modell Deutschland

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Nächster Halt Kohlendioxid-Entnahme? Die deutsche Klimapolitik als riskanter Weg zu negativen Emissionstechnologien

Zusammenfassung Sowohl die globalen als auch die deutschen Klimaziele sind ehrgeizig angesichts der jüngsten Emissionsminderungsraten. Zusätzlich zu den Maßnahmen zur Emissionsminderung wurden in letzter Zeit zunehmend CO_2-Entnahme diskutiert und erste Maßnahmen entwickelt, um zur Erreichung der Netto-Null-Ziele in Zukunft negative Emissionen zu generieren. In diesem Artikel führen wir eine politökonomische Analyse der historischen Entwicklungen und der strukturellen Bedingungen der deutschen Klimapolitik durch und untersuchen, welche Rolle sie für das Entstehen und die Stärkung der politischen Optionen zur CO_2-Entnahme spielen. Wir beziehen uns dabei auf die Regulationstheorie und den Ansatz des *Modell Deutschland* und argumentieren, dass sich innerhalb dieses Modells das Konzept der ökologischen Modernisierung als dominanter Ansatz zur Regulierung der gesellschaftlichen Naturverhältnisse durchgesetzt hat. Angesichts der ehrgeizigen klimapolitischen Ziele, wie zum Beispiel das netto-Null-Ziel bis 2045, stößt die ökologische Modernisierung an ihre Grenzen und muss neu justiert werden. Vor diesem Hintergrund diskutieren wir im Fazit das Risiko der „mitigation deterrence" im Hinblick auf negative Emissionen und diskutieren alternative Wege zur sozial-ökologischen Transformation.

Schlüsselwörter CO_2-Entnahme · Klimapolitik · Ökologische Modernisierung · Wirtschaftswachstum · Mitigation deterrence · Modell Deutschland

1 Introduction

'We are committed to the need for technical negative emissions and will develop a long-term strategy for dealing with the approximately 5 per cent of unavoidable residual emissions' (Bundesregierung 2021: 65, authors' translation). This quotation from the agreement of the so-called traffic light coalition—consisting of the Social Democratic Party (SPD, red), the Green Party, and the Liberal Party (FDP, yellow)—refers to an increasingly important aspect of climate policy—the need to remove CO_2 from the atmosphere in the future. A distinction is generally made between nature-based negative emissions, i.e., those relating to land use changes such as afforestation, and technical negative emissions—with the focus mostly on bioenergy with carbon capture and storage (BECCS)[1] and (DACCS)[2].

[1] BECCS: 'The combustion of biomass, such as energy crops, wood residues or other plant waste, generates electricity or heat. The CO_2 previously absorbed by the plants from the air is released, captured at the bioenergy plant and stored underground (carbon capture and storage—CCS)' (Leopoldina 2022, p. 8; authors' translation).

[2] DACCS: 'In this process, CO_2 is not absorbed by plants, but by technical facilities. These use chemical binders to extract CO_2 from the ambient air. CO_2 and binder are then separated from each other again, which requires energy. The CO_2 is stored underground (CCS) and the binder is reused' (Leopoldina 2022, p. 9; authors' translation).

The possibility and, more so, alleged inevitability of carbon dioxide removal (CDR) via negative emission technologies (NETs) has gained momentum in recent years in global and national climate politics. Especially the Paris Climate Agreement from 2015 and the publication of the Intergovernmental Panel on Climate Change (IPCC) Special Report on the possibility of reducing global warming to 1.5° indicate the need for CDR (Kreuter and Lederer 2021, p. 1). In this report, the IPCC identifies carbon dioxide removal as a necessary condition for achieving the 1.5° target. Accordingly, the German federal government, too, has taken first steps to establish a CDR governance frame. This is essentially based on the German Climate Change Act, which was originally passed in 2019, but was significantly tightened in 2021 following a partly successful lawsuit by young people (Gerstetter 2023). The growing need for CDR is related to the continuation of an economic growth model and does not consider alternative pathways to social ecological transformation such as degrowth approaches (Keyßer and Lenzen 2021; Gerstenberg 2024). It therefore indicates the close link between CDR development and the maintenance of a capitalist growth model.

At the same time, CDR is not uncontroversial. Particularly under the heading of moral hazard or mitigation deterrence, it is pointed out that the possibility of future CDR could lead to a weakening of efforts to reduce emissions (Markusson et al. 2018; Kreuter and Lederer 2021; Carton et al. 2023). Mitigation deterrence can be very broadly defined as 'the prospect of reduced or delayed mitigation resulting from the introduction or consideration of another climate intervention' (Markusson et al. 2018, p. 1). Markusson et al. (2018) argue that mitigation deterrence can cause severe harms if the 'other climate intervention', in our case CDR, proves to be unsuccessful. In this respect, the debate on CDR points to a field of tension between emission reduction approaches and the potential removal of CO_2 from the atmosphere and the associated power struggles (Brad and Schneider 2023), which are also reflected in German climate policy.

Against the background of the growing importance of CDR in climate policy debates, we explore the historical context and the structural conditions enabling the emergence and strengthening of CDR policy options in Germany. Doing so, we develop an analytical perspective based on political economy approaches and refer to the Modell Deutschland (German model of capitalism) approach (Simonis 1998). We argue that the shift towards CDR is an expression of an escalating and increasingly politicized climate crisis and the result of historically established path dependencies. CDR policies herald a new wave of ecological modernization, which is becoming increasingly difficult to achieve in the face of ecological, social and geopolitical crises.

Methodologically, the paper is grounded in critical realism, a philosophy of science approach beyond positivism and constructivism. According to critical realism, reality is stratified into different ontological domains (Bhaskar 1978, p. 56): the empirical is what we experience, the actual is what happens whether we experience it or not, and the real is the domain of structures and mechanisms from which actual events emerge. Causality is to be understood in vertical rather than horizontal terms since it is structures that have causal powers whose actualization depends on the interaction with the causal power of other structures (Spash 2024, p. 87f.).

This conception of reality allows us to analyze the structures of the Modell Deutschland and its inherent causal powers as enabling conditions for the direction German climate policy has taken and to argue about more and less likely, in the sense of structurally grounded, future potentialities. While structures can be both hindering and enabling for political agency, they do not determine the latter and are always amendable (Archer 1995). For that reason, a critical realist methodology is helpful for the analysis of structured agency and agential structuring.

Empirically, our analysis is based on a qualitative content analysis of key government documents, press releases, reports, and scientific literature. For understanding how the written documents are interpreted and discussed by relevant stakeholders, we conducted six additional expert interviews on the role of CCS and CDR within the current climate policy of the traffic light coalition with representatives from political parties, think tanks, environmental organizations, companies, and business associations in 2023. Both data sources represent sections of the empirical domain and serve as entry points for understanding the underlying structural mechanisms.

The paper is organized as follows: In the second section, we develop the theoretical-conceptual framework of the paper. In particular, we refer to the regulation theory-inspired Modell Deutschland approach to outline the contextual factors of German climate policy. In the third section, we reconstruct German climate policy up to the year 2021 with reference to our conceptual approach in order to identify the structural 'starting conditions' of the traffic light coalition government and its increasing attention to CDR. In the fourth section, we analyze the role of CDR in the government's climate policy and show that the latter has so far rested on three pillars: the stabilization and renewal of the *Modell Deutschland*, measures to reduce greenhouse gas emissions and the introduction of CDR as an additional pillar. In the concluding section, we discuss some problematic future developments that might result from the introduction of CDR and point to an alternative path for a social-ecological (market) economy.

2 The political economy and ecology of "Modell Deutschland"

The Modell Deutschland approach was developed in the late 1970s. The core concern was to define the internal and external determinants of the German model of capitalism that are decisive for its developmental dynamics and coherence (Simonis 1998). We use this approach for conceptualizing the political-economic contextual factors of climate policy development in Germany and thus for theoretically substantiating the abstract critical realist notion of structures in relation to our object of investigation. The Modell Deutschland approach is strongly inspired by French regulation theory which seeks to explain why, despite the immanent contradictions of the capitalist mode of production, a relatively stable constellation of development and economic growth occurred during the Fordist phase within the Western world and in some semi-peripheral states (Lipietz 1988). The central concepts of regulation theory are the 'regime of accumulation' and the 'mode of regulation'. The former refers to the conditions that guarantee the continuous accumulation of capital, whereas the latter refers to the modes of safeguarding the corresponding regime

politically and socially. Aglietta (1979) described the wage relation, the monetary constraint and the forms of competition as central dimensions of the nexus of accumulation and regulation. The state and its embeddedness in international regimes are often mentioned as further important structural dimensions (Jessop 2001). What has received little attention within regulation theory, however, is the relationship between society and nature. Görg (2003) argues, that the regulation of society-nature relations is transverse to all structural forms and plays a decisive role in co-producing them. Therefore, the question arises as to how the relationship between capitalism and ecology is regulated. This is also of crucial importance to understanding the development of Modell Deutschland.

According to Simonis (1998), the German model of capitalism has four key characteristics. First, Germany's integration into the world market via a its dominant industrial export sector, which builds the core of Modell Deutschland and has been a guarantee for high trade balance surpluses for decades. Second, a dependent domestic market which is only of secondary importance for economic development. Forms of competition on the domestic markets should rather increase the competitiveness of the German export sector. Third, a high integration of well-trained industrial workers and their trade unions in a corporatist system. Fourth, a mode of regulation, i.e., trade policy aimed at opening markets for German goods, and a labor, financial and economic policy strongly influenced by the aim of increasing the competitiveness of German industry. Industrial policy also plays an important role, which has traditionally been based on a horizontal approach that strengthens industry as a whole without specifically promoting individual companies or sectors (Aiginger 2019).

In our analysis of the historical context and the associated path dependencies against which German climate policy and the road to CDR can be explained, we focus mainly on the following aspects of Modell Deutschland approach (see Table 1): We trace the role of the German export sector and its international embeddedness (accumulation regime) and set out how its development was shaped by political regulation (mode of regulation). We supplement the original approach with a particular focus on how society-nature relations were dealt with and argue that the paradigm of 'ecological modernization' became the hegemonic mode of regulation (Jänicke 2008). Under the guiding principle of ecological modernization, the state reacted to strong environmental movements that politicized worsening ecological problems. Several environmental policy approaches were introduced that did not endanger the core characteristics of the Modell Deutschland but helped to stabilize and renew the industrial core of Germany (Jessop 1997, p. 564). We will show how this paradigm has come under pressure from worsening climate conditions, geopolitical tensions and domestic contestations but is nonetheless indicative for current debates on CDR.

3 Modell Deutschland and German climate policy until 2021

Before we turn to the current climate policy of the traffic light government, we outline its historical 'starting conditions' by reconstructing German climate policy between 1970 and 2021. In the 1970s, the Fordist constellation of prosperity began

Table 1 Modell Deutschland and its implications for CDR policies

Modell Deutschland	Accumulation Regime	Mode of regulation
Implications for CDR	Export sector: With CDR associated export potentials may become of high importance	State: Funding of research & development as well as politically set market incentives are essentially run by the state (and the EU)
	International embeddedness: Growing geopolitical tensions/tendencies for deglobalization could lead to a more domestic market-oriented development of CDR	Regulation of society-nature relations: The dominant approach of ecological modernization is reaching its limits; potential carbon removals serve to supposedly achieving net zero anyway

to erode. GDP growth rates fell sharply in Germany and other countries. Rising unemployment, inflation, also driven by the oil crises of 1973 and 1979, and growing social protests were expressions of the upheavals. At the same time, the destruction of the natural foundations of life also became increasingly politicized. Among others, the publication of the 1972 report on the limits to growth by the Club of Rome (Meadows et al. 1972) inspired intense debates on the relationship between economy and ecology. In Germany, a strong movement sprouted against the use of nuclear energy which at least in part called for a departure from established ways of nature domination (Rucht and Roose 1999). The German government reacted to the intensification of environmental problems and their politicization by founding the Federal Environmental Agency (UBA) in 1974 and tried to regulate the ecological crisis by expanding environmental legislation.

With the change of government from a social-liberal to a conservative-liberal government in 1982, there was a revaluation of environmental policies. This can be attributed to the fact that the CDU/CSU wanted to take the wind out of the sails of the growing Green Party by creating an environmental profile. Previously, the SPD had blocked more ambitious environmental legislations during its time in government because of its strong links with the coal industry's workforce (Weidner and Mez 2008). After the Chernobyl reactor accident in 1986, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) was founded. It was also the start of an increased focus on the dangers of climate change. This is reflected, for example, in the establishment of the Enquete Commission 'Precautions for the Protection of the Atmosphere' (Enquete-Kommission des Bundestags 'Vorsorge zum Schutz der Erdatmosphäre') (ibid.: 362). As a result, as early as 1990 the German government set a target to reduce emissions in West Germany by 25% by 2005 (ibid.: 363).

According to Brand (1999), the period between 1983 and 1990 was characterized by the concept of ecological modernization gaining acceptance as a leitmotif to regulate society-nature relations. Instead of an irreconcilable opposition between economy and ecology, environmental policy approaches were increasingly perceived as a stimulus for technological innovation and a renewal of the German export model under green auspices, and thus fit very well with the renewal of German capitalism, hence the Modell Deutschland (Jessop 1997, p. 564).

A major reason for a certain loss of importance of climate and environmental policy in the 1990s (Brand 1999, p. 41) were the economic and labour policy challenges posed by German reunification in 1990 (Esser 1998) which reflect an increased neoliberalization of Modell Deutschland (Röttger 2012). Despite the repercussions of reunification, considerable progress was made in the years between 1990 and 1998. Germany became an important driver in the international climate negotiations, which brought about the Kyoto-Protocol in 1997 (Weidner and Mez 2008). Essential climate policy impulses were also set with the introduction of the Electricity Feed-In Act (Stromeinspeisegesetz) in 1991 and various support programs for the expansion of renewable energies (Jacobsson and Lauber 2006). The same applies to the area of energy efficiency.

Further progress was made between 1998 and 2005 by the federal government of the SPD and the newly elected Green Party. The introduction of the Renewable Energy Sources Act (Erneuerbare Energien Gesetz, EEG) in 2000 created the central basis for driving forward the Energiewende and thus for phasing out nuclear and, in perspective, fossil power generation. The introduction of the EEG followed the liberalization of the electricity market. In the 2000s, there was a strong expansion of renewable energies and with these new accumulation areas were opened up. As early as 2003, the Federal Ministry of Economics (BMWi) founded the Renewable Energies Export Initiative as a component of foreign trade promotion to stimulate the export of green energy technologies. Due to the generous exemption of energy-intensive industries from financing the Energiewende, its costs were mainly borne by private households. With this orientation, the Energiewende was fitted into Modell Deutschland and its orientation towards industrial export surpluses. In addition, an eco-tax was passed in 1999, which made the consumption of fossil fuels slightly more expensive giving an incentive for enhancing energy efficiency (Haas 2017).

In 2005, a grand coalition between the conservative parties (CDU/CSU) and the SPD was formed under the leadership of chancellor Angela Merkel (CDU) who stayed in power until 2021 (from 2009–2013 Merkel coalesced with the Liberals). In the same year, the European Emissions Trading Scheme (EU ETS) was introduced. Weidner and Mez (2008) argue that German climate policy was based on three pillars: the expansion of renewable energies, an increase in energy efficiency and the EU ETS. However, the 2010s have been rather disillusioning in terms of environmental and climate policy, especially as the global and financial crisis has led to a strong austerity policy orientation, leaving little room for an ecologically oriented industrial policy. In 2019, Germany's emissions were only about 35% lower than in 1990, putting Germany on track to miss the 2020 climate change target of minus 40% (Agora Energiewende 2020). The target was eventually overachieved due to the economic break-down during the COVID-19 pandemic.

In the late 2010s, the liberal world order began to show signs of erosion reflected on the one hand in the rise of right-wing populist and radical forces, and on the other hand in growing geopolitical conflicts, including those played out through trade and industrial policy (Bieling 2019). The paradigm shift in industrial policy under the Federal Minister of Economics and Technology, Peter Altmaier, with the adoption of a new industrial strategy (NIS) in 2019 should also be seen in this context. The NIS provides for a clear departure from the concept of horizontal industrial policy and

focuses on a much more state interventionist industrial policy aimed specifically at increasing the competitiveness of individual companies or sectors (Schneider 2023, Germann 2023). This is prone to influence the direction of climate policy in Germany as a whole and the prospects for CDR, as we show in the next chapter.

Despite growing geopolitical tensions, important climate policy agreements were reached in the 2010s, most notably the Paris Agreement in 2015. In the European context, which has become increasingly important for German climate policy, the European Green Deal (EGD) was presented in December 2019, setting a net zero target for 2050. Within the framework of the European Climate Change Act adopted in 2020, an emission reduction of 55% by 2030 compared to 1990 levels is stipulated and all initiatives relevant to environmental and climate policy were revised and made more ambitious in the course of the EGD (Haas et al. 2022). Even before the release of the EGD, the German Bundestag passed two important climate laws. First, following the establishment of a commission, a law was passed to phase out coal in Germany by 2038. The decision and the pathway to phase out coal by 2038 was strongly criticized for not being in line with climate policy targets. The criticism was formulated by some members of the commission as well as the oppositional Green Party (Löw-Beer et al. 2021). Second, the German Bundestag passed the first overarching climate protection law in 2019. which was deemed unconstitutional in parts by the German Constitutional Court in March 2021 because it disproportionately restricted the civil liberties of young people (some of whom initiated the lawsuit), as very strong emission reductions were only envisaged for the period after 2030 (Gerstetter 2023). Accordingly, the grand coalition amended the law before the federal elections and anchored a 65% instead of 55% emission reduction target by 2030 with sector-specific targets.

Overall, the current situation is rather ambivalent (Töller 2023). On the one hand, ambitious climate policy goals were adopted, especially in the wake of the Paris Agreement, and a strong and changing climate movement (Fridays for Future, Extinction Rebellion, Last Generation, etc.) is calling for their fulfilment. On the other hand, social and geopolitical tensions are increasing. With the rise of right-wing populist and radical parties, the voices of those who doubt man-made climate change have become more prominent. Therefore, the regulation of society-nature relations presents a major challenge. Previous approaches have failed to reduce emissions sufficiently, while at the same time various crises and conflicts are coming to a head (Brand and Wissen 2024). The challenge for the German government is to renew Modell Deutschland against the backdrop of growing geopolitical tensions and, at the same time, to meet the ambitious climate policy goals that are binding under international law. In the past, it has been possible to reduce emissions through ecological modernization measures in parallel with economic growth, but it is doubtful whether drastic emission reductions (up to net zero by 2045) will actually be possible under the horizon of continued growth and the leitmotif of ecological modernization. We are hence experiencing a situation in which both the accumulation regime and the mode of regulation are thrown into crisis, are increasingly contested from various sides and need to be recalibrated.

4 Traffic-light coalition and German climate policy

We will now discuss the climate policy of the traffic light coalition and its turn to CDR as an attempt to regulate society-nature relations against the background of escalating crises. In the federal election in 2021, the SPD became the strongest party and formed a traffic light coalition together with the Greens and the Liberals under Olaf Scholz as the new chancellor. The new federal government operates programmatically under the label 'Progress Coalition' (Fortschrittskoalition) with the aim of further developing the social market economy into an ecological social market economy. The semantic revaluation of the ecological dimension is certainly based on a general increase in the importance of ecological problems, mainly climate change, in recent years, and also reflects the attempt of the Greens to provide important impulses for strengthening the ecological dimension within the mode of regulation. In addition to the Federal Ministry of the Environment and Consumer Protection (BMUV) and the Ministry of Food and Agriculture (BMEL), the Greens secured the climate-relevant Federal Ministry of Economics (BMWK), which was expanded to include climate protection and is headed by Vice-Chancellor Robert Habeck. The FDP received the climate-relevant Ministry of Transport and Digital Infrastructure (BMDV) in addition to the Ministry of Finance (BMF) while the SPD leads the Ministry of Housing, Urban Development and Construction (BMWSB).

Right from the beginning, there have been massive disputes between the Greens and the Liberals, especially in the field of environmental and climate policy. While the Greens tend to stand for binding targets and correspondingly underpinned governance architectures, the FDP mostly insists on technological openness as the central leitmotif of climate and environmental policy (interviews Agora Energiewende, FDP).

The traffic coalition's climate policy should be oriented towards the implementation of the emission reduction goal of 65% by 2030. The coalition agreed to develop an action program for natural climate protection, a development program to increase the CO_2 storage capacity of the oceans, a national circular economy strategy and an emergency climate protection program, to increase the share of renewable energy sources in the electricity sector to 80% by 2030 (with an expansion target of 200 GW for photovoltaics and 30 GW for offshore wind), and to generate 50% of thermal energy in a climate-neutral way by 2030. In addition, the traffic light coalition also commits to so-called technical negative emissions and declared a 'long-term strategy for dealing with the approximately five percent unavoidable residual emissions' (Coalition Agreement, p. 65, authors' translation). Furthermore, the Russian invasion of Ukraine in February 2022 has severely shaken up the policy of the traffic light coalition, especially in terms of energy policy. More than half of the natural gas consumed in Germany in 2021 came from Russia. The energy source is a central building block for some basic industries (such as the chemical industry) as well as for heating.

In this respect, the traffic light coalition faces a challenge in the energy and climate policy realm that is at least threefold. The first challenge is to stabilize and renew Modell Deutschland. In the past decades, German capitalism was heavily based on the import of Russian gas. In this respect, the year 2022 was mainly characterized

by the need to secure energy supply through saving measures and the construction of LNG terminals on the German North Sea and Baltic Sea coasts. The second challenge is to meet the (short- to medium-term) climate targets enshrined in the Climate Protection Act of 2021. The law provides for concrete sectoral underpinned targets up to the year 2030, in which emissions are then to be 65% below 1990 levels. This path can only be met if emissions are quickly reduced in all relevant sectors (energy, heat, transport, industry)—with the exception of agriculture, where no major emission reductions are foreseen by 2030. The third challenge is to lay the foundations for removing CO_2 from the atmosphere against the background of the net-zero target by 2045. The coalition agreement adopted the distinction between natural and technical sinks. While the action program on natural climate protection aims to increase the storage capacity of natural sinks, the long-term strategy targeted for 2024 aims to define a way of dealing with the remaining approximately 5% of unavoidable residual emissions and also addresses technical sinks. We will consider each of these three challenges and the respective measures of the traffic light government, and discuss the problems that these entail for Modell Deutschland (see Table 2).

4.1 Stabilization

After the Russian invasion of Ukraine on February 24, 2022 a replacement for Russian gas supplies was quickly needed. The German government reacted twofold. First, it took measures to reduce gas consumption. Coal-fired power plants were brought back from the reserve and the nuclear phase-out planned for the end of 2022 was postponed to 15 April 2023. With these measures, gas consumption in the power generation sector was significantly reduced. In addition, energy saving regulations were issued for the winter of 2022/2023 which included reducing the temperature in public office buildings to 19 degrees, lowering the water temperature in public swimming pools and not heating private pools. Gas consumption in 2022 was reduced by 17.6% compared to 2021 (Bundesnetzagentur 2023).

Apart from these restrictions, a massive increase in gas and electricity prices challenged private households as well as German industry. For that reason, a gas and electricity price brake was finally enacted as part of the Energy Security Act. A basic quota is to be subsidized by the state in order to curb rampant inflation. Since Russian (state-owned) companies also play an important role in the gas supply in Germany, the possibilities of fiduciary administration or expropriation have been expanded—for example, the Federal Network Agency was already appointed as trustee of Gazprom Germania GmbH on April 4, 2022. These measures were taken to flank the energy saving measures aimed at securing energy supplies.

The third building block to secure gas supplies is the development of an LNG infrastructure. The German government presented plans for this as early as the summer of 2022. In the same year, the first three special ships, so-called Floating Storage Regasification Units (FSRU), were put into operation. This was hailed by the government as a new, so-called German tempo (Deutschlandtempo). In addition, five more FSRUs were commissioned in 2023 and the construction of three terminals in Wilhelmshaven, Brunsbüttel and Stade began. Many environmental NGOs and

Table 2 Climate policy of the traffic-light coalition

Aim	Stabilization	Emission Reductions	Carbon Removals
Measures	LNG acceleration act Various energy saving ordinances	Reforms of Renewable Energy Act (EEG) Introduction of a Heating Law (GEG)	National Climate Action Program Carbon Management Strategy Long-term strategy for dealing with unavoidable emissions (BMWK 2024b)
Problems	Danger of carbon-lock-ins	Fierce opposition to ambitious climate policies, especially on heating and transport	Lack of clarity about the potential, feasibility, and acceptability of CDR

green think tanks have criticized the adopted plans as 'massively oversized' (Höhne et al. 2022), as they far exceed existing import capacities from Russia. Reducing gas consumption by 20–30% by 2030 is essential to meet Germany's climate targets. These are indications that the stabilization and guarantee of supply security runs the risk of creating a fossil lock-in, which contradicts Germany's climate goals and increases the risk of being dependent on large amounts of CDR.

4.2 Emission reductions

At the start of the government's term, Germany was not on track to meet its 2030 climate target. In 2021, greenhouse gas emissions stagnated at around 761 Mt CO_2. In particular, the transport and buildings/heating sectors were not on track (Agora Energiewende 2022). However, far-reaching targets were formulated in the coalition agreement, particularly in the areas of electricity (expansion of renewable energies) and heat (increase in the share of regeneratively generated heat energy). In the area of transport, the coalition agreement remained entirely unambitious. The BMWK, in addition to playing a central role in orchestrating the stabilization measures mentioned above, is responsible for key legislation that is central to reducing emissions. The first of these is the amendment to the EEG, which was passed without much public controversy in the summer of 2022 and came into force in January 2023. The aim is to increase the share of renewable energy to 80% of electricity consumption by 2030 through measures to speed up planning and permitting, the rapid expansion of grid infrastructure and higher remuneration for solar power. The EEG levy has already been abolished in 2022 (Bundesregierung 2023a). The Wind on Land Act (Wind-an-Land-Gesetz), which came into force in February 2023, obliges the federal states to designate at least two per cent of their land area for wind energy by 2032—to prevent individual federal states, such as Bavaria, from slowing down the expansion of wind energy with restrictive state laws.

The amendment of the Building Energy Act (Gebäudeenergiegesetz, GEG) has led to much greater controversy. According to the first draft bill, a ban on the installation of new oil and gas heating systems was to be brought forward from 2025 (as envisaged in the coalition agreement) to 2024. A massive campaign against this proposal was launched by Germany's leading tabloid newspaper 'Bild'. As a result, the bill was criticized not only by the opposition parties but also increasingly by the FDP (Deckwirth 2023), and numerous regulations have since been watered down.

The installation of gas heating systems should still be possible if they can also be operated with hydrogen (although there is widespread agreement that heating with hydrogen is also not a viable way of achieving the climate targets, Kreutzfeld 2023). In addition, the law has been more closely linked to municipal heating planning and it has been agreed that homeowners will receive support from the Climate and Transformation Fund (Klima- und Transformationsfonds, KTF) when they replace their heating system. The KTF is financed by a special fund that originally consisted of unused funds from the COVID-19 pandemic stimulus package and revenues from German and European emissions trading. It is a significant source of funding to accelerate ecological modernization, for example through subsidies for the expansion of the e-charging infrastructure, the hydrogen economy or the modernization of the building stock. However, the German Federal Constitutional Court ruled in favor of a complaint by CDU/CSU MPs that the transfer of funds not used during the COVID-19 pandemic to the KTF violates the debt brake. As a result, the funds in the KTF have shrunk significantly by 60 billion euros and numerous planned grants have been canceled (Bundesregierung 2023b). This shows that there is a tension between ecological modernization and the austerity policy that is a key component of Germany's high trade surpluses.

In February 2024, Habeck presented the key points of a carbon management strategy (in the coalition agreement, the finalized strategy was announced for autumn 2023). The carbon management strategy focuses on CCS and CCU, with only a brief mention of CDR. The key points indicate that a CO_2 storage and transportation infrastructure shall be constructed, and CO_2 shall be stored in the German North Sea (BMWK 2024a). While there is considerable support for this, the broad scope of CCS application is highly controversial. Only the combination of coal-fired power with CCS is to be prohibited, while gas-fired power plants are to be allowed to use CCS (although no subsidies are planned for this application).

The picture of the coalition's success in reducing emission is ambivalent. Even when the coalition agreement was adopted, it was clear that the transport sector, along with the building sector, would continue to perform significantly below average. As a result of the 2021 Climate Protection Act, Federal Transport Minister Volker Wissing was forced to draw up an immediate emissions reduction program in 2022 and submit it to the Climate Expert Council. The Council refused to review the emergency program because it proved to be completely inadequate (Expertenrat für Klimafragen 2022a, p. 5).

But not only for the transport sector but for the economy as a whole, the Council of Climate Experts comes to a sobering conclusion for the year 2022: 'In general, the emission reduction rates achieved so far are far from sufficient to achieve the climate protection targets for 2030—neither in total nor in the individual sectors' (Expertenrat für Klimafragen 2022b, p. 15; authors' translation). Nevertheless, emissions declined considerably in 2023, dropping by approximately 10% from 750 billion tons to 674. The Council of Climate Experts attributes this notable decline primarily to a reduction in production in emissions-intensive industries and mild weather conditions (Expertenrat für Klimafragen 2024).

Despite the significant decline in emissions in 2023, climate policy has been a highly contentious issue within the coalition. With the approval of the SPD, the

FDP was able to prevail on key points. In March 2023, the coalition committee passed a 'Modernization Package for Climate Protection and Planning Acceleration' (SPD 2023). This includes a relaxation of the Climate Protection Act. Instead of binding emission reduction targets for individual sectors, there will only be overall targets in the future according to plans of the traffic light coalition (Tagesschau 2024). Furthermore, motorway projects will also benefit from the acceleration of planning. In this context, the FDP fundamentally insists on the position of technology openness in the climate policy debates, which Lamb et al. (2020) classify as a 'discourse of delay', as it is often used to delay necessary climate policy decisions. The often-fierce disputes over climate policy regulation demonstrate that the approaches to accelerating ecological modernization within Modell Deutschland are highly controversial and that the established forms of nature domination are quite stable. Both the expansion of LNG infrastructure and the relaxation of the GEG carry the risk of prolonging fossil path dependencies. This points to the debate on mitigation deterrence and the danger that inadequate approaches to emission reductions are offset by potential, but highly uncertain, future carbon removals.

4.3 Carbon dioxide removal

Against the background of increasing challenges to stabilize Modell Deutschland and rather sobering emission reduction achievements until 2022, the possibility and necessity of CDR measures are being brought on the table. So far, CDR is more of a future vision than an actual climate policy practice. Even on a global level, technical CDR methods (such as BECCS, DACCS, biochar or ocean alkalinization) only account for a marginal share in absolute terms so far (Smith et al. 2023). It will be a great challenge to increase nature-based CDR and massively expand technical CDR methods (ibid.), particularly because it is highly uncertain to what extent CDR will be possible in the future at all (Lawrence et al. 2018). At the same time, it is undisputed that the net zero target by 2045 cannot be achieved in Germany without removing CO_2 from the atmosphere, as long as further economic growth is assumed, and greenhouse gases will continue to be emitted in some sectors such as agriculture or the cement industry (interviews Agora Energiewende, Bellona).

Against this background, the traffic light coalition has largely been oriented towards the targets set out in the Climate Change Act of 2021, which defines removal targets for the LULUCF (land use, land use change and forestry) sector for 2030 (25 Mt CO_2), 2040 (35 Mt CO_2) and 2045 (40 Mt CO_2). These targets for conventional, nature-based CDR are also reaffirmed in the Natural Climate Action Program (Aktionsprogramm Natürlicher Klimaschutz) (BMUV 2023) which was adopted in 2023 under the leadership of the BMUV and has a total budget of four billion euros until 2026. An important part of this is to increase the removal of CO_2 from the atmosphere.

It is worth noting that the coalition's decision on the modernization package for climate protection and accelerated planning was accompanied by a commitment to CDR and also technical negative emissions (novel CDR technologies). It thereby hints at the possibility of mitigation deterrence effects. The paper states:

'To achieve the goal of net greenhouse gas neutrality in 2045, natural sinks and technical sinks such as bioenergy with carbon capture and storage (BECCS) or direct atmospheric carbon capture and storage (DACCS) will play a role in offsetting unavoidable emissions. The German government will set a negative emissions target for the years 2035, 2040 and 2045. This will be done for the first time in 2024 on the basis of the long-term strategy for dealing with unavoidable residual emissions envisaged in the coalition agreement for that year' (SPD 2023, p. 3; authors' translation).

The above-mentioned long-term strategy for dealing with the approx. 5% of unavoidable residual emissions (Langfriststrategie zum Umgang mit unvermeidbaren Restemissionen) harbors considerable potential for conflict. Habeck presented key points of this strategy (BMWK 2024b), together with the key points for the carbon management strategy in February 2024. Here the question arises as to which emissions are actually unavoidable, i.e., may still be emitted after 2045 (cf. Lund and al 2023). This, in turn, raises questions about which industrial and also agricultural processes will still be possible after 2045 and to what extent. Our interview data indicate that some companies have so far refused to electrify their production processes because CCS and hydrogen are discussed as options for reducing emissions in the future (interview Agora Energiewende).

While all governing parties are committed to the paradigm of 'ecological modernization', there are different interpretations of it—particularly between the Greens and the FDP. It is very controversial within the coalition how incentives for CDR should be set and to what extent CDR will be possible. While the FDP argues that the market for CDR should not be restricted from the outset, the Greens tend towards a much more restrictive definition of unavoidable residual emissions and the resulting need for CDR (interviews Agora Energiewende, BDI, FDP). However, the definition of future CDR is highly dependent on the widespread availability and social acceptance of negative emission technologies, both of which are far from certain (Lawrence et al. 2018). In this respect, growth limits are at least implicitly negotiated in these disputes—because it is evident that the lower the economic growth, especially in carbon intensive sectors, the lower the need for CDR and the greater the likelihood that climate targets will be met (Hickel et al. 2021). In addition, the development of negative emissions, especially from novel CDR, also has considerable potential for conflict. BECCS and DACCS are based on the development of a CCS infrastructure. CCS was massively controversial in the late 2000s, which was one of the reasons why it was not pursued further in Germany at that time (interviews BDI, MAN ES).

The potential disputes over CDR are also mediated with the conflicts over the national industrial strategy. The FDP has spoken out against the abandonment of a horizontal industrial policy. For the Greens, on the other hand, restructuring industry to meet climate targets under the leitmotif of ecological modernization is not possible without a more interventionist, targeted industrial policy (interview Agora Energiewende). Against the backdrop of rising geopolitical tensions and correspondingly more protectionist and interventionist industrial policies, there may well be scope to align CDR along these parameters. In 2022, the US passed the Inflation Reduction Act (IRA) which contains numerous subsidy opportunities both in the

green energy sector and for CDR. The EU reacted with the Net Zero Industry Act (NZIA), which also expands subsidy opportunities while further weakening European competition law (EU COM 2023). This trend towards a more vertically oriented industrial policy is likely to be important for the development of CDR. According to the Global Status Report on Carbon Dioxide Removal, the majority of CDR patents are held in China. In 2018, China accounted for 36% of all CDR-related patents (Smith et al. 2023, p. 30). In this respect, the industrial policy dimension could play a significant role in the future, should CDR technologies take off.

So far, however, CDR has only played a niche role in climate policy—although there is an intense debate under the heading of mitigation deterrence as to whether the possibility of CDR potentially occurring in the future will lead to a correspondingly less committed approach to emission reduction measures (interview NABU). This field of tension can be observed both in the global context and in the national context of Germany. So far, CDR has hardly played a role in Modell Deutschland, but there are recognizable initiatives to establish a CDR policy in Germany and the EU (Schenuit et al. 2023).

5 Conclusion

In the past, Modell Deutschland has proven to be both stable and capable of change at the same time (Czada 2019). So far climate policy under the guiding principle of ecological modernization which focuses on technology, competitiveness and growth and is therefore compatible with the Modell Deutschland has not been sufficient to put Germany on a path compatible with the Paris climate goals (at least not without the help of an economic recession). At the same time, according to the Climate Protection Act of 2021, Germany is supposed to achieve the net zero target in 2045. This will require a massive restructuring of the entire industry (the core of Modell Deutschland). However, regulation of society-nature relations is contested and despite broad agreement on the concept of 'ecological modernization', measures to reduce emissions are often highly controversial. The Greens prefer a more state interventionist policy, corresponding with the 2019 NIS, which is widely described as an industrial policy paradigm shift (Schneider 2023). Whereas the FDP draws heavily on the concept of technology openness and has successfully pushed for a relaxation of the 2021 Climate Change Act, departing from binding sectoral targets. The failure to meet the recent climate targets and the alarming strength of the far-right AfD indicate that the disputes over climate policy will probably continue to intensify in accordance with the crises of society-nature relations. Against this background, CDR is currently being established as a new element of climate policy and has so far been little publicly politicized, whereas potential conflicts abound. While the future will show which of these conflicts will be actualized and how, we will briefly discuss some problematic future developments that may result from the adoption of CDR and point to an alternative path for a social-ecological (market) economy and accompanying eco-social policies.

The adoption, and even only the prospect, of CDR measures is linked to the risk of 'mitigation deterrence', i.e. decreased efforts to reduce emissions (Markusson

et al. 2018; Carton et al. 2023). In fact, there are several problems associated with CDR. DACCS technologies are highly energy-intensive and therefore dependent on a massive development of renewable energy capacities that, in turn, are also needed for the electrification of industrial processes, heating, and transport. BECCS technologies are dependent on large areas of land for the cultivation of bioenergy plants (IPCC 2018, p. 343). Recent studies have shown that BECCS would likely induce severe water stress on cultivation areas (Cheng et al. 2022) and cause negative risks on biodiversity and potentially on food security (McElwee 2021). What is more, storage capabilities for CCS technologies 'are by far not distributed evenly across regions or nation states' (Kreuter and Lederer 2021, p. 6). This and the fact that large cultivation areas are not available everywhere might trigger further geopolitical tensions (ibid.). These problems challenge the assumption that CDR will ever be available on a large scale. At the same time, the promise and the prospect of CDR can lead to decreasing ambitions regarding mitigation measures, especially so under the given structural constraints, institutional arrangements and corresponding power relations (Brad and Schneider 2023).

Therefore, the debate of alternative pathways (departing from the path dependencies of Modell Deutschland) to solving the climate crisis becomes ever more pressing. A number of integrated assessment model studies have recently shown that steady-state or degrowth scenarios are compatible with the 1.5 degree target with only a low demand for NETs (e.g. Keyßer and Lenzen 2021; Sers 2022; Li et al. 2023). These models assume that drastic emission reductions can be reached by 'an equitable, coordinated and democratic reduction in socially unnecessary production and consumption' (Li et al. 2023).

Due to both, the aforementioned risks and uncertainties associated with CDR and the established difficulties of decoupling GDP from 'energy, material and fossil fuel use' (Keyßer and Lenzen 2021, p. 2), degrowth scenarios are less risky than growth scenarios in technical terms. Nevertheless, degrowth scenarios are so far hardly considered in the debate due to their 'speculative nature' (Gerstenberg 2024). Particularly in contrast to growth scenarios that are taken very seriously, it is worth stressing a point made by Martin Sers:

'While the speculative nature of degrowth modelling and its attendant assumptions may raise criticisms, it is necessary to note that many common assumptions (continual decoupling of energy from GDP or mass deployment of NETs) are in any sense similarly speculative or unproven' (Sers 2022, p. 11).

On the contrary, the degree and pace of absolute decoupling of GDP growth from CO_2 emissions (not to mention resource use) has been shown by several studies to be incompatible with the 1.5° objective (e.g. Hickel and Giorgos 2020; Haberl et al. 2020; Brockway et al. 2021). The challenges of degrowth scenarios, on the other hand, concern socio-political questions of transformation since a degrowth society does not simply imply economic downscaling but changed social relations. This gives rise to the following, rather comprehensive question: Under what conditions are societies willing and able to adopt a degrowth pathway to sustainability? Engaging with the politics of degrowth contains research on the emergence and effect of new narratives and future imaginaries (Schoppek 2020; Marquardt and Nasiritousi 2022), on strategies and pathways of transformation (Wright 2010; Schoppek and

Krams 2021; Barlow et al. 2022), as well as the design of institutional setups and policies (Joutsenvirta 2016; Buch-Hansen and Koch 2019; Fitzpatrick et al. 2022). Such a transformative perspective also sheds light on the issue of hard-to-abate and associated residual emissions. As Lund and al (2023) have argued, residual emissions are a 'discursively constructed' concept that is 'historical[y] and geographical[y] contingent'. Process emissions that are technically impossible to abate but socially necessary from today's point of view, may no longer be so in a transformed society with changed social needs (ibid.).

Summing up, there is at least a threefold challenge for future research on CDR in Germany and beyond: First, it is necessary to analyze the relationship between CDR and climate policy as a whole (and whether mitigation deterrence effects occur); second, it is necessary to find out how CDR reconfigures the regulation of society-nature relations and the link between the accumulation regime and the mode of regulation; third, it is important to situate the development of CDR in the context of escalating crises and conflicts. While the latter are certainly related to CDR policies, they are rooted in deeper societal conflicts about the future of our mode of living and can therefore only be comprehensively addressed by politicizing the structural mechanisms of a social-ecological market economy that remains anchored in capitalism.

6 Appendix

List of referenced interviews:

- Agora Energiewende (27 March 2023)
- BDI—Federation of German Industries (Bundesverband der Deutschen Industrie) (16 February 2023)
- Bellona (31 January 2023)
- FDP—Free Democratic Party (Freie Demokratische Partei) (19 July 2023)
- MAN Energy Solutions (15 March 2023)
- NABU—Nature and Biodiversity Conservation Union (Naturschutzbund Deutschland) (9 February 2023)

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