

Article

Fixed Amidst Change: 20 Years of Media Coverage on Carbon Capture and Storage in Germany

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Abstract: Carbon capture and storage (CCS) technologies are controversially discussed worldwide. Germany is no exception. Here, CO₂ storage is banned, although successful pilot plants were installed in the late 2000s. However, the recent burgeoning political interest in this technology prompts us to investigate why and how the (public) image of CCS technologies has changed over time and with regard to different CCS applications. For this purpose, we examine the coverage of CCS in German newspapers over the last 20 years on the basis of a quantitative analysis of about 4000 newspaper articles. A sample of 571 articles with different political orientations was studied qualitatively to analyse reporting on different CCS frames and actors. We find evidence that the media debate is shifting towards the application of CCS for negative emissions technologies and carbon removal. However, the negative image of CCS connected to coal fired power plants persists, suggesting that public and political support remain a problem for a technology fixed in binary negotiations for or against it.

Keywords: carbon capture and storage; CCS; newspaper analysis; climate policy; negative emissions technologies



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1. Introduction

The technology of capturing CO₂ and storing it underground is polarising worldwide. While some perceive carbon capture and storage (CCS) as a glimmer of hope for reducing the human carbon footprint, others fear the unknown consequences of such an underground intervention or a delay in decarbonisation efforts. These or similar controversies can be found in Japan, Australia, the USA, Scandinavia, and many more (see for instance growing debates in India [1] or China [2]). In the early 2000s, Germany seemed to be an exception. Hailed as forerunners in implementing CCS onshore, German scientists showed that carbon dioxide could be successfully and safely captured and stored at a pilot site in Ketzin. This project faced little to no public and political opposition [3]. Today, CCS is banned throughout the whole country. This drastic change in the circumstances for CCS implementation makes the German case instructive for international comparisons and other deployment attempts.

CCS technologies have been discussed and studied in Germany for about 20 years. Following the initial success of the pilot facility in 2008, larger industrial initiatives by energy producers showed interest in the onshore storage of CO₂ captured at lignite power plants. These projects faced strong public and political opposition (for instance, because of concerns about leakages, climate policy impacts, and energy companies as project developers) as well as funding problems, which eventually led to their discontinuation, e.g., [4]. Due to the unpopularity of large scale CCS projects among the public, CCS lost its political support and faced subsequent regulatory challenges with the introduction of a new CCS law in 2012 [5]. This law included stricter rules for the carbon-capture process and the

monitoring of storage sites, enabled federal states to prohibit CCS, and set 31 December 2016 as a deadline for CO₂ storage project applications. Since this deadline expired, the geological storage of CO₂ in Germany—onshore as well as offshore—faces a severe regulatory lock-in [6].

However, in recent years, CCS has been reframed in policy papers and governmental assessments. The discourse has increasingly moved away from the application of CCS in the fossil-fuel energy sector and towards residual emissions from industrial processes (e.g., steel or cement production) and negative emissions technologies (e.g., bio-energy with carbon storage (BECCS) or direct air capture with carbon storage (DACCS)), e.g., [7]. This is apparent in the German climate-protection program [8], the latest governmental report on CCS [9], and in the recently published coalition agreement of the newly elected German government [10]. These documents discuss new technological applications as well as offshore storage in the North Sea and suggest a renewed dialogue on CCS. Since public opposition has been a major reason for the disappearance of CCS from the political discourse in the past, the question arises whether the shift in political focus is also linked to a change in the public's image of the technology. Media coverage plays a significant role in shaping the public's opinion and has been shown to influence public concern regarding climate change, e.g., [11], and people's perceptions of science and technology [12]. It should be noted, however, that media representations, especially on emerging and controversial technologies, have been connected to issues such as polarised or selective reporting, e.g., [13,14].

So far, there has been little research on the German CCS media coverage. The few existing studies focus on periods (2004–2013) in which the discourse evolved around the capture and storage of CO₂ emissions at coal-fired power plants [15,16]. Therefore, they could not address the significant shift in the political discourse nor the accompanying media coverage. Our analysis aims to fill this research gap and explore how CCS has been depicted in different socio-historical settings, especially with regard to different applications beyond its link to fossil-fuel power generation. We argue that in light of the new political and technological developments, it is necessary to revisit media representations of CCS in the German news, as this will enable us to understand the frames that media reports provide for societal deliberations on renewed attempts at deploying CCS in Germany. These considerations lead to the central research questions of this study: how is CCS portrayed in German newspapers and have these portrayals changed over time and for different applications? To answer these questions, we examine the coverage of CCS in national newspapers over the last 20 years and specifically ask: (1) how has the intensity of coverage on CCS changed over time, (2) to which applications is CCS connected, (3) in which frames is CCS represented, and (4) which actors support different frames?

Our empirical analysis consists of both quantitative and qualitative content analyses. Quantitatively, we aim to identify general trends in newspaper coverage of CCS and thus observe changes or continuities within the media discourse. Additionally, a sample of 595 articles from newspapers with different political orientations is studied qualitatively to investigate in depth the frames and actors involved in CCS reporting.

1.1. Media Framing and Public Perception

Though it is not plausible to conceptualise the relationship between audiences and media as a linear one in which media producers transmit messages to passive receivers, e.g., [17,18], it is widely acknowledged that media representations affect political debates and public perception. For instance, media coverage has been shown to influence public concern regarding climate change, e.g., [11,19], and people's perceptions of science and technology [12,20]. Several studies indicate that media portrayals of controversial topics and technologies can be associated with polarising or selective reporting, e.g., [13,14]. Research on the portrayal of nanotechnology in the media has emphasised that mass media is "the main information source for most adults about emerging technologies" [21] and that the framing of risks and benefits in news reports is a key factor in shaping public thinking

about technologies [22]. With regard to energy technologies, Delshad and Raymond [23] report that media framings of biofuel influence public attitudes. Ho et al. [24] point to the relation of media reports on preparedness for nuclear crises to public trust in nuclear energy, and studies on the framing of wind power stress the impact of news media representation on people's understanding and opinions of this technology [25].

Here, we focus on the dynamics of CCS coverage and the frames in which CCS is portrayed, as well as the societal actors referenced in media reports. Following Feldpausch-Parker et al. [26], we argue that the perception of CCS is not only constructed through technical and economic processes but also through discourse. Rather than being a given entity, CCS is constituted in "historically situated real social practices" [27] and can be constructed differently according to the *frames* mobilised by different actors, cf. [28,29]. In this study, to frame is understood as "to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation" [30]. Frames, therefore, both reflect and influence how an issue is understood and interpreted.

1.2. Media Coverage of CCS in Germany and Abroad

For the German context, only two studies have investigated representations of CCS in media reports so far. Pietzner et al. [15] analysed articles from regional newspapers published between 2007 and 2011. They selected the case study areas and newspapers according to four CO₂ storage projects that were either operating or scheduled to operate in the area. Working with 1115 articles, they conducted quantitative and qualitative content analyses and found that the coverage peaked in 2009. The authors noted an overall negative evaluation of CCS projects by the press. However, they observed regional differences between commercial CCS projects (in North Frisia, Altmark and East Brandenburg) and research sites (Ketzin)—the latter being viewed as more neutral. The most frequently mentioned topics regarding CCS addressed "political processes", protests against CCS, and specific CCS projects [15]. Energy companies (Vattenfall, RWE) and citizen initiatives were identified as central actors.

More recently, Schneider [16] investigated leading actors in the public discourse on CCS in Germany. He argued that the CCS coverage evolved according to political developments, that CCS nearly vanished from the media agenda after 2012, and that economic and political actors were dominant in the newspaper coverage. However, these claims rely on a narrow conceptual framework and problematic empirical decisions. The analysis is limited because 'coal' and 'CCS' were connected in the keyword search, thereby capturing only a selective part of the debate.

More comprehensive results are provided by international media analyses on CCS, as summarised below. Here we found:

1. Various studies report that media attention given to CCS is focused on specific projects rather than on the technology as a climate change mitigation option, e.g., [31,32]. Peaks in the number of news articles were noted around climate conferences, prominent national or international political or scientific documents about CCS—such as the IEA CCS roadmap [33] or reports published by the Intergovernmental Panel on Climate Change [34]—and (alleged) malfunctions at demonstration sites, e.g., [35,36].
2. The application of CCS in fossil-fuel-based energy production (predominantly coal) was identified as a focal point of media attention, whereas other possible sources such as biomass were rarely covered, e.g., [37,38].
3. Depending on regional and national contexts, the arguments for or against CCS and the emphasis on risks or potentials differed greatly and changed over time—often related to particular events such as the start of a new project or malfunctions [35]. For instance, CCS as a climate-change-mitigation option is an important frame in Japan [39], Australia [31], the US [37] and Norway [32], often building on the metaphors of 'clean coal' or 'green oil'. In contrast, de Best-Waldhober et al. [40] hardly find this con-

nection between CCS and climate change in Dutch newspapers. Changes of frames according to political and economic dynamics are retraced by Nerlich/Jaspal [29], who identify a “hype-disillusionment cycle” in the UK media reports on CCS in 2011 related to the planning and cancellation of storage sites at Peterhead and Longannet. In their international comparison, Dowd et al. [36] point out that economic viability and safety questions are dominant in mainland Europe, whereas articles from the UK, for example, emphasise funding problems.

4. The reference to actors in media reports and their role in framing CCS is addressed in few studies. Asayama & Ishii [39] find an overrepresentation of “policymaking elites” (government bureaucrats, industrial groups, researchers) in the Japanese newspapers articles and a marginalisation of environmental non-governmental organisations (eNGOs) and citizens. Industry representatives were found to be the most frequent speakers in CCS related news items in the Finnish print media, followed by technical experts, administration (e.g., representatives of ministries or municipal administration), and NGOs. Citizens’ voices played only a minor role in the articles [32].

In this study, we use these findings as a guide for the empirical analysis of our data and as a backdrop for the discussion of our results.

2. Materials and Methods

We collected newspaper data from a news aggregator database (wiso-net) that covers national and regional German newspapers and contains about 180 million articles published between 1 January 2000 and 31 December 2020. The starting point of our data collection was chosen in accordance with the start of early CCS research projects that assessed geological storage capacities in Germany [41].

We chose a broad set of keywords to ensure a sample representative of newspaper articles that is not bound to one application of CCS and, thus, allows us to track changes in technology discussions over time. The keywords refer to common descriptions of CCS in Germany (e.g., “CCS” AND “CO₂”; “Speicherung” AND “CO₂” AND “Untergrund”) and additionally target CCS projects (e.g., “Sleipner” AND “CO₂”; “Ketzin” AND “CO₂”) (see Figure 1 for an overview of the keywords and the sampling process).

We followed a two-step sampling strategy. First, we collected articles from the entire German press database to create a comprehensive corpus for the quantitative analysis of reporting intensity (here understood as the frequency of articles dealing with CCS). We identified 6228 articles in the wiso-net press database. After removing 2221 duplicate records and excluding 32 articles after screening because they did not address CCS, our sample for quantitative analysis consisted of 3975 articles.

The second sampling step formed the basis for the qualitative content analysis. Articles from three German newspapers with nationwide circulation and different ideological standpoints were drawn from sample 1 to analyse the influence of political stances on CCS coverage, see [39]. We included the following newspapers: The conservative newspaper *DIE WELT* (and its online outlet *DIE WELT online*), the liberal news outlet *Frankfurter Rundschau* (FR), and *Die Tageszeitung—taz* (TAZ) as green and left-wing newspaper; compare, for instance, [42,43]. This second sample encompassed 571 articles.

We employed both quantitative and qualitative methods of content analysis. For the quantitative content analysis [44], we imported all articles in the software R to calculate word frequencies and occurrence rates over time. To do so, we cleaned the data by removing article duplicates, numbers, punctuation, and stop words (i.e., articles, pronouns). Based on that, term-document matrices were created, enabling the analysis of how often words occurred.

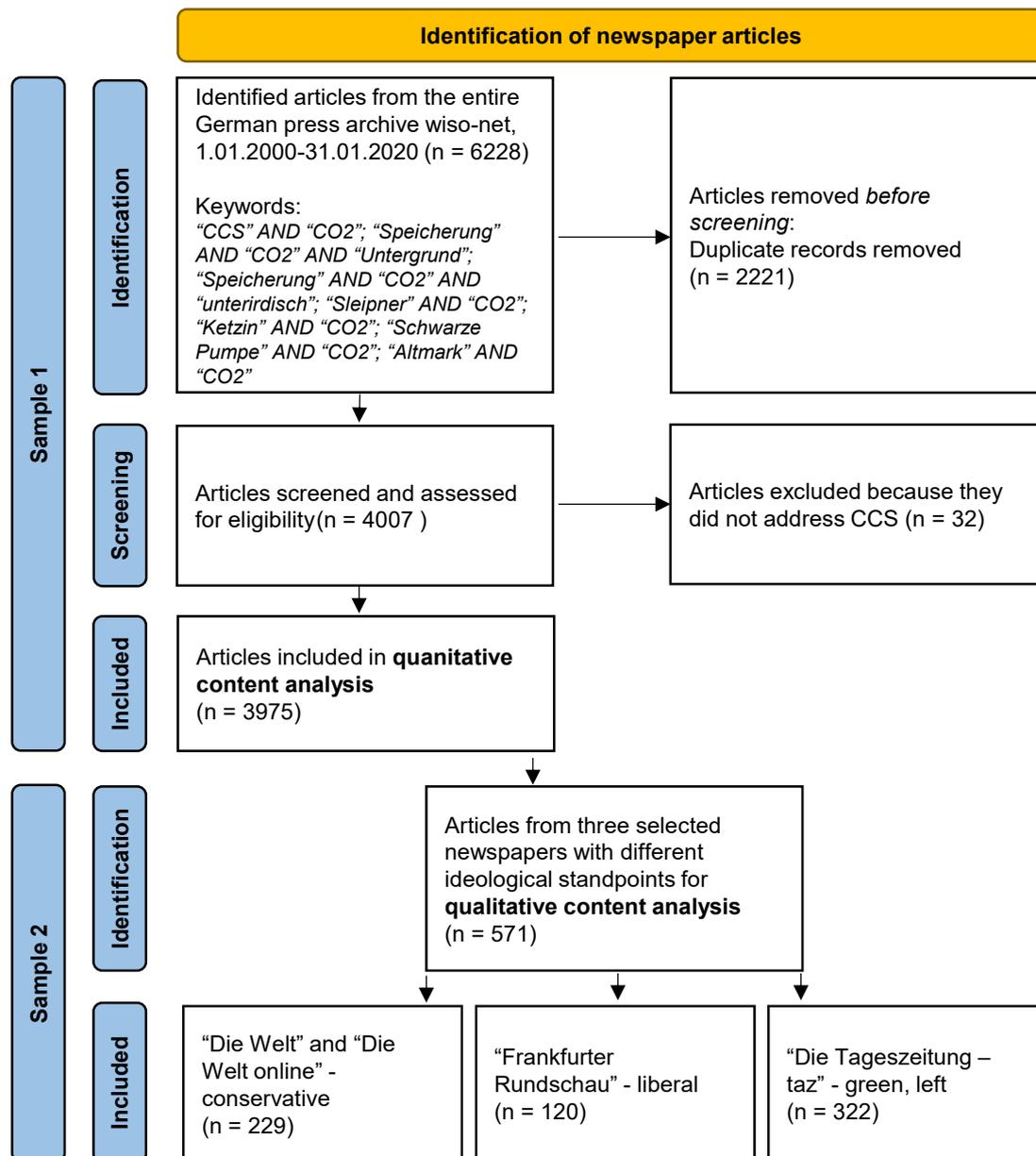


Figure 1. Overview of keywords (We checked for other keywords that are often linked to CCS—such as negative emissions, bio-energy, carbon capture and storage, and direct air capture—to verify that our sample covers a broad range of CCS applications and is not limited by undetected changes in common vocabulary), sampling, and analysis.

To delve deeper into the data and understand how CCS has been framed in the material, we conducted a qualitative content analysis of the second sample. Following Schreier [45], we applied a coding strategy that combined inductive and deductive reasoning. For the first round of coding, we established six broad categories guided by our research questions and previous literature, e.g., [37], that covered (1) potentials, (2) risks, (3) insecurities, (4) representations, (5) applications of CCS, and (6) the political debates on CCS as reported in the newspapers. Furthermore, we coded all actors that were mentioned in the articles. Actors were defined as individuals, groups, or organisations that are described as doing or saying something in an article [46]. Two researchers (D.O. and M.P.) independently coded the articles with this pilot phase coding frame ('blind' coding) to identify relevant segments. During this process, disagreements were discussed and code descriptions were refined. The discussions among the coders also served as a basis for

the in-vivo development of sub-categories. Code refinement and the development of sub-categories resulted in an improved codebook that was applied in the main round of coding (an overview of all codes is provided in the Supplementary Materials, Table S1). In this main coding process, the data was separated into three parts. The two coders worked through two parts independently and the third part was coded by both [45]. To ensure consistency, the coding of this third, overlapping part was compared and discussed [45]. The coding process was considered completed as soon as the two coders came to approximately the same coding results independently of each other. It must be noted that the numbers of codes produced in this process represent coder observations rather than measurements or counts of occurrences [47]. The codes, therefore, serve to identify prominent frames of the coverage and are analysed as interpretations of the material. We derived the main frames inductively, based on the sub-categories [46,48].

3. Results

3.1. Development of CCS Coverage over Time

Results regarding the number of CCS news articles per year show that media reporting on this subject got off to a slow start during the exploration phase of CCS in Germany (2000–2005). This was followed by an uptick in reporting during the starting phase of German CCS projects (2006–2008) and a peak in media attention on CCS between 2009 and 2012 (see Figure 2). A significant reduction in article numbers can be observed after 2011. From 2013 onwards, we see reduced but stable article numbers before a slight increase in CCS coverage after 2018.

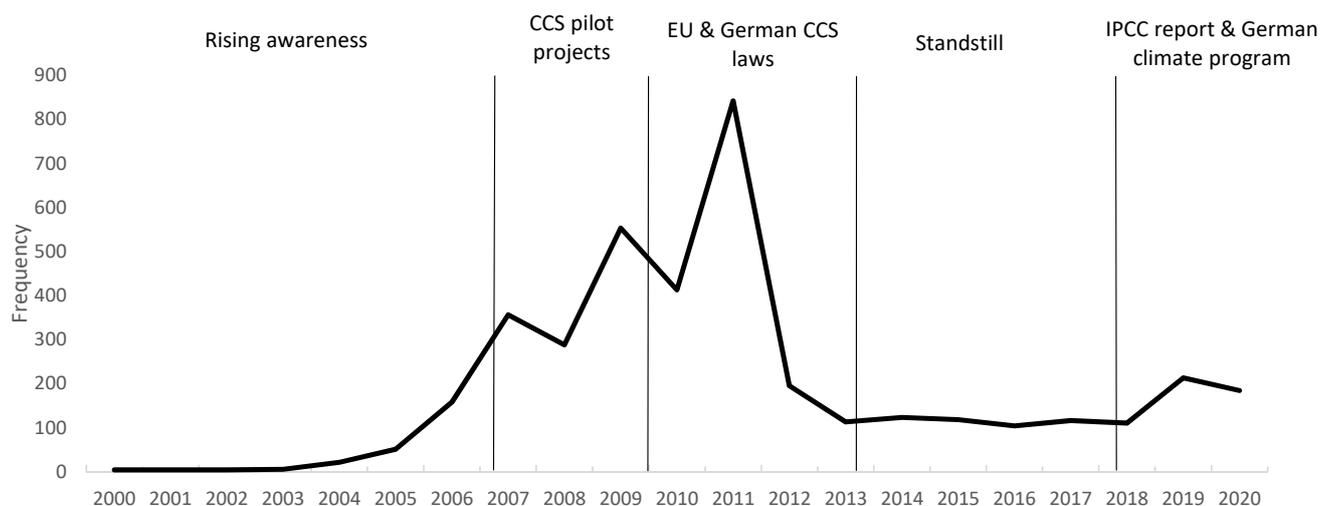


Figure 2. Article numbers per year (sample 1—all newspapers in the wisonet database; N = 3975).

Turning to sample 2, we find a pattern of coverage similar to that of sample 1. There are, however, differences in the number of articles between the three newspapers. Reports on CCS can be found significantly more often in TAZ than in WELT or FR between 2006 and 2015 (Kruskal-Wallis test, $H(2) = 9.490$, $p = 0.009$). The article numbers only align during the first (2000–2005) and last years analysed (2016–2020) (see also Figure S1, in Supplementary Materials).

Building on a research strategy used in analysing Finnish print media reports on CCS [32], we identify five phases of coverage based on the article frequency and historical developments related to CCS policy and deployment (see vertical lines in Figures 2 and 3 for an overview of the phases). We use these time periods to distinguish patterns in the depiction of CCS.

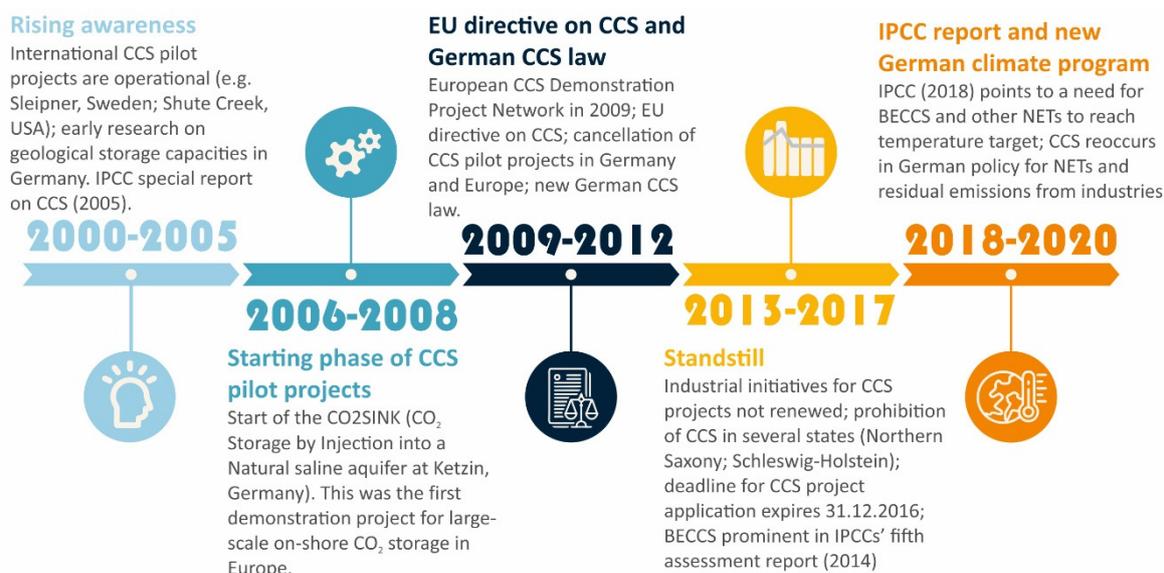


Figure 3. Overview of CCS coverage time periods and CCS applications.

3.1.1. Rising Awareness 2000–2005

The few articles on CCS in the early 2000s mainly report on international projects and explain the CCS processes in detail for sites such as Sleipner (Norway) or Peterhead (UK)—all of which relate to fossil-fuel use. They also touch upon early research on geological storage capacities in Germany. The IPCC special report on CCS [49] became a reference point in a few articles in 2005. Only the TAZ and WELT published articles on CCS in this early stage, and both provide comprehensive technical descriptions. In this phase, energy companies, eNGOs, and scientists lead the debate about CCS.

3.1.2. Starting Phase of CCS Pilot Projects 2006–2008

Article numbers rise as CCS became a more political topic. While the majority of the reports still referred to the start of the demonstration projects (for instance, at Ketzin) and detailed technology descriptions remained an important part of the articles, the political dimension of CCS began to take up more space. As energy companies (e.g., Vattenfall, RWE, E.ON) planned to utilize CCS to capture CO₂ at lignite-fired power plants, controversies with political actors at federal, regional, and local levels received more attention during this period. Detailed technology descriptions remained widespread. WELT and FR focused mainly on the northern German states with plans for CCS projects between 2006 and 2008 (as they have the largest geological capacity for storing CO₂, e.g., Brandenburg, Schleswig-Holstein) and the political parties in power there. Articles in TAZ, however, more frequently referred to state (e.g., German Chancellor Angela Merkel) and non-state actors such as the EU, UN, and non-governmental organisations.

3.1.3. EU Directive on CCS and German CCS Law 2006–2012

From 2009 onwards, coverage intensity reached its peak as media attention moved away from the novelty of storage sites and coverage of individual projects. While large initiatives for pilot sites started at the European level—such as the European CCS Demonstration Project Network established in 2009 [50]—political and legal controversies surrounding CCS took centre stage. Public protests and political opposition against the plans of energy companies to build CCS infrastructure for coal-fired power plants or enhanced oil recovery in several parts of Germany (e.g., Wilhelmshaven, Beeskow, Salzwedel) dominated the news. Furthermore, the implementation of the EU directive on CCS [51] in German legislation and the controversies accompanying this process are other main issues addressed in the analysed newspapers. This legislative procedure gained much media attention because

it took three years and three attempts to pass the new law on capturing, transporting, and storing CO₂ in the German Bundestag and Federal Council. Many reports zoomed in on the division of political parties as well as federal ministries concerning the risks and potentials of CCS. Towards the end of this phase, the cancellation of CCS projects—linked to lack of political support, regulatory insecurities, and financial problems—became a focal coverage point. Energy companies continued to play an important role as supporters of CCS. eNGOs and local citizen initiatives took a leading position as opponents of the technology. Attention was also given to the political parties in federal states (Brandenburg, Schleswig-Holstein, Lower Saxony) and communes with ongoing plans for CCS sites. On the national level, coverage centred on parties in the German Bundestag and the conflicts surrounding the CCS law. The capture of CO₂ from the fossil-fuel power sector remained the primary application discussed in all three newspapers.

3.1.4. Standstill 2013–2017

The number of articles significantly decreased in this phase as CCS was prohibited in several Federal States with storage capacities, and industrial initiatives for CCS projects were not renewed. The deadline for CCS project application expired 31 December 2016 and made further project proposals impossible. However, we find a shift from German to international discussions on climate change, and stories about CCS featuring technical details reappeared in the news coverage between 2013 and 2017. While a focus on fossil-fuel energy production persisted, articles also addressed new applications and novel international developments in carbon storage (e.g., the Carbfix project in Iceland). For instance, we find articles that explain the operating principles of BECCS, but those articles do not include detailed information on CCS (e.g., the transport or storage operations). This interest for new applications coincided with the increased relevance of scientists and scientific institutions as actors in the media reports. Most prominently, the IPCC, which points to BECCS as a viable technology to reduce the human carbon footprint [34], is portrayed as supportive of geological carbon storage in all three newspapers. On local, regional, and national levels, energy companies and political actors were less represented, while international organisations (e.g., UNEP, EU) became more important. Citizen initiatives disappeared from reporting in this phase, leaving eNGOs and the Green Party as dominant actors on the opposing side.

3.1.5. IPCC Report 1.5 and the New German Climate Program 2018–2020

In the last period, the trend towards more diverse CCS applications continued. More attention was given to BECCS, DACCS, and the storage of residual emissions from industrial processes (e.g., steel or cement production) or from hydrogen production ('blue hydrogen'). The main technical principles behind these innovative applications are explained, but the technical details of CCS are rarely reported. This development is linked to the importance that is given to BECCS and other negative emissions technologies in the IPCC special report on global warming of 1.5 °C [52] and the recurrence of CCS in German climate policy [8,9]. We find that the IPCC and German politicians (mostly from the conservative party) are portrayed as proponents of CCS. The Green Party and environmental activists are most prominent on the opposing side. However, the news reports also show that opposition to CCS from eNGOs has waned and that applications of CCS beyond the fossil-fuel industry are discussed.

By tracking the development of CCS media coverage over two decades, we can identify five phases of reporting and find changes in article frequencies, referenced actors, and CCS application. The main focus of the articles rests on the use of CCS to capture emissions from coal-fired power plants and the political discussions about this application option. Other methods of CCS usage appear in media reports after 2013, with stronger links to scientific actors and significantly less intensity.

3.2. Framing CCS

After outlining the trends in reporting on CCS over the last 20 years and the actors involved in the ongoing discourse on CCS, we want to delve deeper and focus on the framing of CCS. We identified five main frames: (1) “Clean coal”, (2) CCS as a climate-change-mitigation option, (3) CCS as prolonging fossil-fuel use, (4) CCS as a risky technology, and (5) CCS as not politically feasible in Germany. These frames are interlinked and overlap to some degree, but each one accentuates a certain aspect related to CCS and makes it salient.

3.2.1. “Clean Coal”

Presenting CCS as an option to mitigate CO₂ emissions from coal-fired power plants—often dubbed “clean coal”—is the major frame in all three newspapers until 2009. It highlights CCS as a way of combining climate change mitigation with the continued use of fossil resources for power generation. Such reports often feature professionals from energy companies and illustrate their views. The economic potential of “clean coal” was stressed in the early years of CCS newspaper coverage. From this point of view, the application of CCS in the power sector promised an increase in jobs (or at least job security for the coal industry), export opportunities for CCS technology (for instance, to China or India, who are viewed as likely to continue using coal), and an overall reduction in the cost of the energy transition. Energy security through the prolonged use of coal was another argument that was repeatedly brought forth in this line of reasoning and positioned CCS in connection with coal as a “bridging technology”. The “clean coal” frame became strongly contested during the discussions on the German CCS law and lost its dominant position from 2009 onwards.

3.2.2. Prolonging Fossil Fuel

The prolongation of fossil-fuel use through CCS application is the main negative frame between 2006 and 2012. CCS is portrayed as a mere legitimization for energy companies to build new coal-fired power plants and continue business as usual by employing technology with unclear feasibility and unforeseeable risks. It is argued that climate goals will not be achievable with additional coal power stations, even if CO₂ is captured. Furthermore, any focus on CCS technologies would delay the energy transition, because attention and funding would not be focused on the preferential expansion of renewable energy generation. This frame is mostly connected to eNGOs or Green Party politicians in the newspaper articles and is most frequent in TAZ during the discussions of the German CCS law (2009–2012). It is much rarer in WELT and FR.

3.2.3. CCS as a Climate Change Mitigation Option

In a broader and highly contested frame, the climate change mitigation potentials of CCS are either highlighted or questioned. On the one hand, CCS is represented as a promising climate change mitigation option. On the other hand, CCS is depicted as a “false hope” with overestimated potentials and unclear feasibility that would most likely have negative effects on initiatives to limit climate change. Although these frames are present throughout the coverage, the arguments for or against the mitigation potential change multiple times.

Parallel to the dominance of “clean coal”, early articles on CCS (until 2009) stress the efficiency of capturing CO₂ from big emitters such as power plants to significantly reduce global carbon emissions. Pilot projects (Ketzin) and successful international examples (e.g., Sleipner in Norway) testify to the feasibility and measurable impact of CCS. This position appears in all three newspapers and is mostly supported by energy companies and political actors. With the discussion of the German CCS law and the public and political pushback against CCS connected to coal, the discourse changed after 2009 and especially after 2012. The mitigation potential of CCS plus coal is depicted as a point of contestation among politicians, eNGOs, and energy companies. The articles describe a hope for climate-neutral coal usage but also highlight the insecurities and open questions associated with this hope.

After 2012, discussions of the mitigation prospects are mostly disconnected from coal-fired power plants. CCS in connection to coal only appears as an option for limiting global warming when articles take a global perspective that links to the prolonged usage of coal in developing economies. Other applications receive more attention, such as capturing CO₂ from cement plants or generating negative emissions through BECCS or DACCS. This development is connected to the increased relevance of scientists in the articles as proponents of CCS. The IPCC becomes a central actor and reference for the necessity of some form of CCS to achieve temperature targets. We can see this dynamic in all three newspapers. However, compared to the high number of articles that linked the climate mitigation potentials of CCS to coal up until 2012, this strand of discourse remains small.

3.2.4. CCS as a Risky Technology

We find strong variations in reports on CCS risks from newspaper to newspaper and over time, as different economic, environmental, and health-related questions concerning the feasibility and safety of CCS are discussed. Economically, the high investment and operating costs as well as limited efficiency feature as risks. Furthermore, the uncertain technical feasibility of long-term storage below the ground is raised as an investment risk. This is strongly related to environmental risks such as the possibility of saltwater from CO₂ reservoirs entering the groundwater, induced seismic activity due to the injection of CO₂, and the sudden eruption of CO₂ from leakages.

Many articles liken CCS to radioactive waste disposal. This comparison is present from 2006 until the end of the observation period. It is most prominent between 2009 and 2012 and most often used in the TAZ. From this perspective, CO₂ shall be stored interminably (“CO₂ Endlager”) with unpredictable but potentially devastating impacts on the environment. Directly connected to these environmental issues, the newspapers address risks to human health, like suffocation through an explosive eruption of CO₂ from a reservoir leakage.

Reports on risks became more frequent after 2005, peaked during the CCS legal debates between 2009 and 2012, and decreased after CCS was banned in the most relevant federal states. The main actors that pointed to the risks of CCS were anti-CCS citizen initiatives, local politicians, eNGOs, and Green Party members. We see that environmental and economic risks enter the debate earlier and stay in the reports longer than the risks to human health, which are only prevalent between 2009 and 2012. Throughout all periods, risks, especially environmental risks, are most frequently discussed in TAZ articles.

3.2.5. CCS as Not Politically Feasible in Germany

The last frame we commonly encountered in our analysis emphasises that CCS is not politically feasible in Germany. It is argued that CCS will not find public and political acceptance because of risk perception, high costs, and the overall questionable feasibility of effective carbon storage. The frequency of this frame increased in 2009 after public protests and political opposition grew louder during the debates on the German CCS law. It persists in articles published after 2012, even though no more protests occurred as projects ended or project plans were discarded. The technology’s political feasibility is questioned because further protests are anticipated should CCS projects be restarted. Furthermore, the prohibition of CCS in Schleswig-Holstein, Lower Saxony and Mecklenburg-Western Pomerania and the deadline for further CCS project applications (in 2016) are discussed as strong political barriers. Since political parties are unwilling to engage with such a contested technology and overcome existing regulatory barriers, CCS is represented as politically impossible. This frame is present in all three newspapers, and we rarely found statements that directly contest it.

4. Discussion

This paper aimed to analyse the depictions of CCS in German newspapers to understand if and why they have changed over time and for different applications and what

implications this could have for future plans to implement CCS projects in Germany. By examining the coverage of the last 20 years and analysing actors and frames in the CCS media discourse, we found overlaps with previous research but also key issues that deviate from past findings.

4.1. Intensity of Coverage

We were able to identify five phases of CCS media coverage based on the article frequencies and historical developments concerning CCS policy and deployment portrait in the articles. Compared to previous studies in the UK, these phases indicate a longer “hype-disillusionment cycle” for CCS than in other national and social-historical contexts [29]. The hype for “clean coal” as the dominant application of CCS started in the early 2000s and was amplified by the initial success of the scientific pilot study at Ketzin, before it turned into disillusionment by 2012 after the cancellation of industrial efforts, public protests, and the regulatory prohibition of CCS.

The most visible increases in article numbers are linked to the introduction of new CCS projects, the debates on the CCS law, and—to a lesser extent—the release of climate reports and policies. We see a distinct decrease in media attention after the passing of the CCS law in 2012 and the subsequent regulatory barriers for further CCS initiatives in Germany. Similar to previous studies [15,16], we find that CCS article numbers peaked in 2009. The number of articles produced during this peak period differs between the three newspapers, with green and left-leaning outlets publishing significantly more reports. After that, the numbers decline, but we do not find evidence for Schneider’s [16] claim that CCS “nearly completely vanished from the media agenda” after 2012. Instead, the number of articles remained low yet stable, with a slight uptick in reports after 2018.

4.2. Framing CCS

We find that CCS pilot and demonstration projects as well as political protests and controversies garner the most media attention and that CCS is primarily reported on in relation to its use in the fossil-fuel energy sector. Both findings fit the insights from previous research, e.g., [15,38,40]. Like other studies, e.g., [31,53], we were able to show that the coverage’s evaluation of CCS was mixed, and we identified five partially contradictory frames. The reason for the mixed coverage is that the framing of CCS heavily depends on how CCS technology is applied, the actors that feature in the reporting, regulatory developments, the newspaper, and when the article was published.

Taking the example of “clean coal”, the most prominent frame in our analysis, we see that it emerges and declines along with political and industrial ambitions and is strongly linked to energy companies as proponents of CCS plus coal. If other actors, for instance eNGOs, feature in the articles, the “clean coal” argument becomes contested, and CCS tends to appear in a “prolonging fossil fuels” frame instead. Likewise, we find that the frame that positions CCS as a climate change mitigation option shifts as new actors (IPCC, climate scientists) gain attention in news media: instead of an emphasis on the benefits of CCS plus coal, the potentials of technologies like BECCS or DACCS are highlighted instead. Which actors and frames are featured in the articles also depends on the newspapers. We find more critical discussions and reports that take up statements and positions of anti-CCS actors in FR (liberal) and TAZ (green, left-leaning) compared to WELT (conservative). In the latter, pro-CCS actors (especially industry representatives) and positive evaluations of CCS are more common.

4.3. Shifts in Frames, Applications, and Actors

Our analysis shows that the framing of CCS in newspaper articles changes considerably over time and that the introduction of the CCS law in 2012 is the pivotal point for the German media discourse on CCS. Despite some minor exceptions, CCS was initially reported on as a way of combining climate change mitigation with a continued use of coal.

The number of frames increased as this application became contested and different actors competed for interpretational power to define what CCS is and can do.

With political and industrial interests in “clean coal” and pilot projects focusing on CCS at coal-fired power plants, it does not come as a surprise that this frame was dominant up until 2012. It is, however, surprising that CCS in connection to coal remained a prominent point of reference for arguments against CCS during the entire time period analysed. Other possible CCS applications gained importance after 2012 and especially after BECCS featured prominently in IPCC reports [34,52], but so far with a lower frequency of articles and without the hype that accompanied “clean coal”.

Another unexpected discovery was that the distinction between offshore and onshore CCS options hardly played a role in the coverage. Considering the relevance of protests against previous CCS projects (all planned onshore), we presumed this distinction would have attracted more attention.

Additionally, our analysis shows that the discussion of risks increased in the context of political and legal debates on CCS. The number of articles on risks grew quickly with the controversies surrounding the CCS law until 2012 and declined rapidly afterwards. We find more reports on risks in the left-leaning TAZ than in the liberal (FR) or conservative (WELT) outlets.

All newspapers, however, include misleading characterisations of CCS that overstate the risks of this technology—for instance, by likening the risks of carbon storage to that of permanent radioactive waste disposal. This comparison is most striking as it is present throughout much of the analysed years of media coverage, taps into a long-running, controversial environmental debate in Germany, e.g., [54], and implies the comparability of the risks and problems of two very different uses of the subsurface.

Parallel to these shifts in frames and applications, we find that energy company representatives disappeared as proponents of CCS after 2012 and the discontinuation of planned projects. Afterwards, scientists played a larger role as advocates for CCS utilisation outside the fossil-fuel energy sector. In terms of opposition to CCS, citizen initiatives are central actors in articles with regard to specific regional CCS projects. eNGOs and politicians of the German Green Party feature as opponents to CCS throughout the entire 20 years. As the discussion of CCS reluctantly turns to negative emissions technologies and residual emissions after 2012, we find a partial change in the strict anti-CCS positions of eNGOs that fits previous research, e.g., [55].

For policy-makers, our analysis and the shifts in frames, applications, and actors outlined above provide an opportunity to reflect on the shortcomings of previous policy measures for CCS deployment in Germany and to consider more participatory approaches for CCS deployment in the future. Given the multitude of relevant actors, concerns (e.g., prolonging fossil-fuel use) or misconceptions (e.g., radioactive waste management), and the various options for integrating CCS applications into climate policy, conflicting views seem inevitable. Not trying to avoid or control these conflicts, but taking them into account and providing arenas for debate amongst the relevant actors identified in our analysis (e.g., politicians, industry, scientists, eNGOs, (local) citizens, and media representatives) *before* renewed deployment efforts could help carbon storage technologies out of the entrenched portrayal as ‘not politically feasible’ in media reports and in the public eye.

4.4. Fixing CCS

Last, we argue that the meaning of CCS became rigid and fixed in the German media discourse for multiple reasons. We find that technical descriptions of CCS are most prominent in early reports on the technology and in reference to pilot sites. As the novelty of CCS wears off and political controversies about its use become the newsworthy events, the level of technical detail decreases. This dynamic has led to a transformation of CCS in the news media from a complex technology that is still under development, comes in various configurations, and is discussed for its climate change mitigation potential into a seemingly established technology with predetermined risks and specifications. CCS has become a

fixed construct associated with public rejection, economic inefficiency, political risk, and radioactive waste. We argue that this process of fixing is strongly marked by the dominance of CCS in connection with coal-fired power plants in media discourses and has negatively affected the discussions of any technology that depends on carbon storage. When applications such as BECCS or DACCS appear in articles, their technical details are introduced, but information on CCS stays one-dimensional. So, even though we find changes in the frames, actors, and applications of CCS over 20 years, CCS is portrayed as simplistic and with the blemish of a failed technology connected to fossil-fuel power generation and as a technology that lacks public, financial, or political support. Despite the technical, legal, social, and political complexities that are connected to considerations on potential deployments of CCS, it appears in the media reports as a technology that can generally be rejected or endorsed. It remains to be studied how the media discourse will develop after discussions on negative emissions technologies and the removal of residual emissions have gained momentum in the political sphere [10] and if the increased importance of scientists (especially the IPCC) as actors in the news reports will influence this.

In this sense, our findings correlate with and go beyond previous research on media representations of CCS, e.g., [29], and other emerging or controversial technologies in different settings, e.g., [13,14]. Our analysis can thus contribute to a better understanding of the mediatisation of such issues beyond Germany. The German case may be instructive in how media debates stuck in binary negotiations for or against CCS can easily move into a fixed position with little room for negotiation, experimentation, and thus new technical and societal developments. Since similar tendencies to pigeonhole controversial technologies in policy debates and media representations have been observed before—take, for instance, criticisms of the diesel engine [56] or discussions of “nature-based solutions” for climate change [57]—it would be worth conducting comparative analysis to study communication mechanisms involved in such processes. It remains an ongoing task to monitor the developments in national and international carbon-storage media discourses and to study how they interrelate with the public perception of CCS, climate policies, and scientific assessments. For this purpose, it will be important to approach the public understanding of CCS with future studies that analyse other relevant media arenas, such as television or social media. In addition to the analysis of media reports, which can be assumed to influence the perception of technologies [19] but do not reflect the public’s attitude towards them, further research on the uptake of media reporting as well as quantitative and qualitative assessments of the perception of different CCS applications are necessary.

5. Conclusions

We can conclude that CCS has been a highly charged term in the German news media over the last two decades and remains controversial until the end of our observation period. In recent years there are indications that the media coverage is changing, with new technologies reluctantly entering the debate and actors shifting. However, we also note that earlier, more prominent discussions about CCS and its former main application linked to coal-fired power plants persist. Often the media representation is stuck in pro and con loops, relying on fixed portrayals of CCS that pull the risks and potentials of the technology to extremes. Given this media coverage in German newspapers, public and political support is doubtful. For renewed public and stakeholder dialogue on CCS and its possible role in climate policy [8], political actors would be well advised to reflect on the interplay between media and politics in relation to this technology and to consider the continuing influence of previous attempts to deploy CCS in Germany. Based on the relevant actors and themes we found in our study, one promising approach for decision-makers would be to enter into an exchange with eNGOs, scientists, industry, and (local) citizens in order to discuss the negative associations with nuclear waste and coal. Addressing these controversial issues head-on, and using participatory approaches to devise future

carbon-storage initiatives that prevent the prolongation of fossil-fuel use, could help CCS out of the fixed position it often occupies in the media.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su14127342/s1>, Figure S1: Article numbers per year (sample 2—DIE WELT, *Frankfurter Rundschau*, *Die Tageszeitung—taz*); Table S1: Codebook.

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