

This is the preprint peer-reviewed version of the following article:

Rowland, J., López-Asensio, S., Bagci, A., Delicado, A., & Prades, A. (2023). Shaping information and knowledge on climate change technologies: A cross-country qualitative analysis of carbon capture and storage results on Google search. Journal of the Association for Information Science and Technology, asi.24828

which has been published in final form at: <https://doi.org/10.1002/asi.24828>

This preprint has been updated to reflect changes made in the final version. Please refer to the published version for citing purposes.

Shaping information and knowledge on climate change technologies: A cross-country qualitative analysis of carbon capture and storage results on Google search

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Abstract

Commercial search engines play a central role in shaping, defining, and promoting the information people have access to in contemporary societies. This is particularly true when it comes to emergent technologies, for which there is often limited available information in legacy media and other sources, thus having a strong bearing on public perceptions. In this article, we focus on how the Google search engine promotes information on carbon capture and storage (CCS). We explore how Google's ranking parameters and interface shape the information people access when searching for CCS through a qualitative analysis comparing the results in three countries (France, Spain, and Portugal). We focus on the content of the first search engine result pages (SERP) and consider both Google's ranking criteria and the content and format of promoted sources. The study reveals Google's influence in highlighting Wikipedia pages, Q&A-formatted sources, and prioritizing online specialized media and private corporations. Additionally, we observe country-specific variations in terms of actors and types of content, reflecting the level of interest and investment in the topic at the national level. These findings underscore the significant role of search engine mediations in shaping public perceptions and knowledge about emergent climate change technologies.

1. Introduction

Search engines such as Google have assumed paramount importance in how people search for and access information in their daily lives. They act as a mediating infrastructure, making information available to the general public, while also shaping the conditions in which this information is filtered and made visible (Haider & Sundin, 2019). They are, in this sense, not a neutral medium, often becoming a site of struggle for attention from different actors and mirroring specific social and cultural dimensions of the content they provide (Eklöf & Mager, 2013).

Their mediating role makes search engines a central element in the production, distribution, presentation, and accessibility of information across the world. They not only hierarchize social relations and entities (Iliadis, 2022) but also influence what people know or ignore in different moments and contexts, ultimately shaping the knowledge produced on topics such as environmental issues or new and emerging technologies (Eklöf & Mager, 2013; Haider & Rödl, 2023). This is particularly relevant because internet sources are increasingly used as legitimate sources of information on scientific and technological issues (Oltra et al., 2014).

In this article, we explore these processes by comparing the results obtained in three European countries (France, Spain, and Portugal) when searching for information about a specific climate change-related technology: Carbon Capture and Storage (CCS).¹ The study originates from research focused on the social acceptance of CCS in three European countries – France, Spain, and Portugal - taking into account the information that citizens would encounter when seeking information about the technology.

CCS is a fairly new technology aimed at mitigating climate change by sequestering CO₂ from industrial emitters and permanently storing it underground, in depleted oil or gas reservoirs or deep saline aquifers. It differs from other technological strategies to tackle CO₂ emissions such as Carbon Removal (CDR) because it focuses on preventing CO₂ emissions from entering the atmosphere, while CDR seeks to actively reduce atmospheric CO₂ concentration utilizing methods like natural CO₂ sinks, direct air capture, or CO₂ utilization. The risks of CCS include potential leakage, safety concerns, and technological challenges (Pires et al., 2011). On the other hand, risks associated with CDR encompass environmental impacts, scalability issues, and, like CCS, the potential to hinder more ambitious climate action goals (Carton et al., 2020). Although some CCS facilities already exist, the technology is still undergoing development in terms of geological, technical, economic, and social research. As a result, it remains relatively unfamiliar to the public (Ha-Duong et al. 2009; Itaoka et al. 2013; Ashworth et al. 2015).

CCS is recognized as a valuable tool by the IPCC (Intergovernmental Panel on Climate Change) and the European Commission for mitigating emissions from energy generation and industries that still rely on fossil fuels (IPCC, 2022; Lipponen et al., 2017). It has gained support from companies and some governments, and there are already operational CCS facilities in the US and Norway, where carbon is stored in depleted offshore oil fields. However, European governments have been slower in adopting this technology (Karimi, 2017; Tsvetkov et al., 2019). Environmental NGOs and certain political actors oppose CCS, arguing that the costs and insufficient development are incompatible with the urgent need for emission reductions and divert attention and resources from other solutions, such as renewable energies. Public awareness of CCS is limited, leading to a predominantly negative perception (Oltra et al., 2010; Vercelli et al., 2013). When faced with specific CCS projects, local communities often oppose

them due to concerns about potential environmental and health risks, resulting in some cases in project cancellations (Kuijper, 2011; Oltra et al., 2012; Braun, 2017).

CCS is, therefore, a controversial and relatively unfamiliar technology. It is reasonable to assume that this controversy is reflected in the media and online sources. Among studies on the social acceptance of CCS, only a few have included media analysis and these studies have mostly focused on legacy media (Buhr & Hansson 2011; Shackley et al. 2012; Brunsting et al. 2015; Otto et al., 2022). However, there is an extensive tradition of examining the role of media in energy technology controversies, as they shape how innovation processes are perceived and discussed by the public (Dowd et al. 2011, Eklöf & Mager 2013). Furthermore, in some cases, they can amplify perceptions of risk (Lofstedt, 2015, Ashworth et al., 2015).

In the three countries, the level of public discussion on the topic is relatively low. Currently there are no commercial-scale CCS projects, but the level of policy development and engagement with the topic varies (Dütschke et al., 2022a). In the French press, for example, there is a greater abundance of articles on the subject; however, they are mostly brief and there is a significant proportion of negative stances towards CCS. Media coverage of CCS in Spain tends to focus on national issues, but the topic is more referenced than thoroughly discussed. Nonetheless, most press articles are positive towards CCS. In Portugal, media coverage is scarce and mostly neutral towards CCS (Prades et al., 2022).

We aim to expand this research by exploring the role of search engines, specifically Google, in these processes. Our objective is to shed light on the mediating role they play in promoting knowledge on this topic, with a particular focus on how this differs across the three countries under analysis.

2. Background

Information retrieval on Google is not solely associated with the content of the information, as is the case with traditional bibliographic information systems. According to Haider and Sundin (2019), it is structured around multiple criteria, including the user's needs, the relevance of the information in relation to those needs, the users' interaction with the platform, and the volume of available data upon which the system relies. It is important to note, however, that Google is a multisided platform with commercial interests, serving different "clients" such as web searchers, marketers, and businesses, among others (Sundin et al., 2021). All of these are considered when defining relevance and producing results (Haider & Sundin, 2019).

The commercial interests on the platform can influence search results in different ways, as noted by Lewandowski and Schultheiß (2022, p. 2): through the promotion of content associated with subsidiaries of the search providers themselves, through the use of keyword-based advertising, or through search engine optimization (SEO). SEO refers to the practice of optimizing web pages to improve their ranking and visibility in organic search results (Lewandowski et al., 2021; Li et al., 2014). Research has shown that SEO has a considerable impact on the content promoted by search engines like Google, often resulting in the domination of SEO-optimized results on Google's first page of search results (Lewandowski & Schultheiß, 2022). SEO is one of the most influential activities in the field of online marketing (Giromelakis et al., 2019) and is estimated to have multimillion-dollar value (Lewandowski & Schultheiß, 2022).

Search engine providers often offer guidelines and other resources that web providers can use to optimize their websites and improve their visibility. On Google Search Central, for example, Google provides ample information on how to improve the SEO of a website. This can include using specific types of structured data markup, “standardised format for providing information about a page and classifying the page content” (Google, no date), such as FAQ, Q&A, How-to, and many others. These formats have a significant impact on the promotion of a result by Google, as they have a higher probability of being displayed as a rich result (like a featured snippet) on the search results page.

SEO processes not only influence the way content is presented and designed but also how it is produced by web providers (Lewandowski & Schultheiß, 2022). Studies have shown their impact in the field of journalism, for example, where its adoption directly affects the way journalists write, promote and share content (Giomelakis et al., 2019). The importance of certain strategies and standardized formats for Google's SEO has different implications for content creation. On one hand, it incentivizes the use of typified formats for knowledge production and dissemination, or, in other words, the adoption of typified, semantically embedded, rhetorical genres (Andersen, 2008; Brannon et al., 2022). On the other hand, it also incentivizes the production of low-quality content by web providers wanting to gain visibility on the platform (Lewandowski & Schultheiß, 2022).

These processes introduce structural incentives for the type of information shared and promoted on the internet, which are not necessarily related to the content itself and are mostly invisible to the general public. In their recent investigation in Germany, Lewandowski and Schultheiß (2022) showed that only 8.9% of internet users know the term “search engine optimization”, and only 43% of them indicated being aware that Google ranking results can be influenced by strategies that do not involve paying money. This contrasts with the 79% of internet users who declared knowing the possibility of influencing Google results through paid advertisements.

Users are not only unaware that these processes influence the content they access but also of the ways SEO shapes the manners content is presented to them. Unlike a simple list of organic results, search page results tend to have a complex structure (Schultheiß & Lewandowski, 2021) including different elements like paid advertisements, videos, featured snippets, suggested questions, news, and knowledge graph, among others. The way information is displayed on the page is particularly relevant since users seldom look beyond the first few results (Höchstötter & Lewandowski, 2009). Google's recent move to provide facts, suggest questions and present data directly on the results page reinforces this risk, as it allows users to conduct “zero-click searches”, where they get answers to their queries straight on Google's results page (Iliadis, 2022).

This affects not only how the information is selected in on-page results (what links and sources are presented and how they are ranked) but also how the search is oriented (auto-complete suggestions, related questions, etc.), and how results are presented (extracting information from specific pages - websites, Wiki Pages - and presenting them on the result page). In the last decade, accessing information through Google has become more like accessing a database of facts “or fact-like statements” (Haider & Sundin, 2019, p. 25) making the original sources of information increasingly invisible to users.

All these processes have an impact on the promotion of certain content in relation to others. Gerhart (2014) shows how simple queries tend to give more visibility to the “sunny side” of controversial topics, whereas more diverse queries result in more controversial and analytical

material. Research also shows how search engines and other types of media are often joined together, creating a new “media convergence” that not only tends to exacerbate traditional information biases and hierarchies (Eklöf & Mager, 2013), but can also be actively used to spread misinformation (Tripodi, 2022). Haider and Rödl (2023) work, on the other hand, highlight how content producers and users articulate with the algorithmic and commercial logic of Google to co-produce new knowledge (and ignorance) logics on fundamental issues like climate change.

Comparative analysis of results obtained through search engines in different countries have also highlighted the importance of the contextual level, and how differences at the national level, intersect with search engine processes and regulatory frameworks, resulting in different results and experiences for users. Diversity of results between countries has been explored, for example, in relation to topics like Covid-19 conspiracy theories (Toepfl et al., 2022) or homeopathy (Cano-Orón, 2019). These studies have highlighted the connection between search engines results and the state of public opinion in different countries (Cano-Orón, 2019), the visibility of mass media organizations across countries (Cano-Orón, 2019; Toepfl et al., 2022), and differences in the levels of problematic content in the results obtained in different country contexts (Toepfl et al., 2022).

In many of these studies, data is produced using automated data collection tools that extract the URLs of specific queries. This type of analysis has the advantage of allowing the comparison of large amounts of data in a systematic way, making visible differences between queries or countries that would not be apparent otherwise (Toepfl et al., 2022). However, the comparison of larger amounts of data often leads to a certain degree of decontextualization of the content promoted in the URLs. As a result, certain differences and specificities of the sources promoted may not be considered. Similarly, extracting URLs often means that, except for the ranking list, the way information is visually presented in the Search Engines Interface is not considered in the analysis. This is a limitation because, as we have seen, Google increasingly extracts information from websites and presents it on its page through information boxes, suggested questions, and featured snippets (Schultheiß & Lewandowski, 2021; Iliadis, 2022). These elements of the SERP interface are central to how people interact with and interpret information through Google search engines (Höchstötter & Lewandowski, 2009; Schultheiß & Lewandowski, 2021).

In this article, we opted to conduct a “search audit” (Metaxa et al. 2021; Mustafaraj et al., 2020; Ulloa et al., 2022) based on a qualitative comparative analysis of a small sample of CCS-related results. This approach allowed us to consider the specificities of the topic under analysis, the SERP interface, and differences between queries and countries.

To achieve this, we analyzed the type of information that people would access when searching for CCS in France, Spain, and Portugal at a specific moment, and we examined if there were any significant differences in the search results between the three countries. Our findings provide meaningful insights into how knowledge on an emergent technology like CCS is shaped through the Google search engine. However, due to the qualitative nature of the study, these insights do not imply generalizability to a broader context.

The research questions that guided our analysis were:

- Q1: What content tends to be promoted by Google in countries with different historic levels of engagement with CCS?

- Q2: How do Google ranking parameters, specific queries, and SERP presentation influence the information on CCS that users have access to when searching for the topic?
- Q3: What implications might these processes have on how information and knowledge regarding an emergent climate-change technology topic are promoted and disseminated in different national contexts?

3. Method and Sample

Our data was generated in the context of the analysis of media representation of CCS in Portugal, Spain, and France (Prades et al., 2022). Our goal was to understand the type of information that Google search engines tend to produce for the topic in the three countries, and whether specific queries associated with CCS, CCS risk, or the country would yield similar results. Due to the absence of an active public discussion on the topic in the three countries and a generalized lack of lay knowledge on the topic (Dütschke et al., 2022a), we opted to use general search terms in our queries², that is, queries that included what we found is the most common term used to designate the technology in print media in the three countries (Prades et al., 2022). We decided to include a query on CCS risk because risk is a highly debated aspect of the technology³ both in CCS academic literature and legacy media (Otto et al., 2022). The inclusion of this search term allowed us to highlight more critical views on the technology⁴ in the three countries. Additionally, we included a query that included the name of the country where the search was performed to understand if this would affect the information obtained. In each country, we conducted queries on Carbon capture and storage; Carbon capture and storage risks; and Carbon capture and storage (name of the country).

Google was selected as the preferred search engine because it represents more than 90% of the search engine market in each of the three countries (StatCounter 2022). The searches were conducted in the national language of each country (French, Spanish, and Portuguese). In France the expression used for CCS was “capture et le stockage du carbone”, in Spain “captura y almacenamiento de carbono”, and in Portugal “captura e armazenamento de carbono”. For easier reading, we will refer to a shortened version of these queries in English⁵ throughout the article regardless of the language in which they were executed.

The analysis specifically examines the first SERP generated by these queries (3 SERPs per country, totaling 9). To collect and analyze the data we created a template for the results of each country. It included of two sections that were repeated for each query. The first section focused on the content that Google promotes directly on the results page (1), while the second section comprised a table to summarize the content of each URL in the organic results list (2). Additionally, the template also incorporated a final section for synthesis and initial interpretation of the country’s results (3).

We also considered that Google search results tend to vary for each user based on their location and navigation history, among other criteria. To avoid personalized results, the template included instructions on the preferred browser, and how to perform the query using an incognito window, after cleaning browsing history and cookies (Haider, 2016).

The data was produced in the three countries between January 28 and January 30, 2022. The searches were conducted in Paris, Barcelona, and Lisbon by a member of each national team,

using www.google.fr, www.google.es, and www.google.pt, respectively. All team members performed the queries on Google Chrome, in an incognito window, with history and cookies cleaned.

Using the information from the templates, for each country and query we compared all the elements of the SERP – search suggestions, suggested questions and answers, featured snippets, information boxes, alternative search terms, and advertisements – aiming to understand patterns, similarities, and differences.

For the list of results, we classified each link in terms of source, type of actor, type of content, as well as the overall evaluation of CCS. During the analysis, we referred back to the original sources whenever necessary to clarify their origin, format, and content.

We evaluated the information about CCS on each source using a classification similar to the one used by Oltra et al. (2014) for analyzing the presentation of nuclear fusion on the Internet. We categorized sources as positive, when they emphasized the benefits and positive features of CCS; balanced when the source presented both arguments for and against CCS⁶; neutral when the source did not include any explicit position towards CCS⁷; and negative when the article had a clear critical view of CCS. This evaluation was initially conducted by a member of each team and later validated by two members of the Portuguese team who are fluent in the three languages.

These steps in our analytical process allowed us to synthesize, classify, and describe the collected data. Our qualitative approach to data analysis aimed to explore how various factors - such as the Google web interface, ranking criteria, Search Engine Optimization processes, topic specificity, content of the promoted URLs, content producers, country and language context, impact the promotion and dissemination of knowledge on the CCS topic. We paid particular attention to patterns that emerged in the comparative analysis, between queries and countries to understand the differences and similarities, which shed light on how Google mediates our access to information on the web. This approach enabled us to identify significant variations in the content promoted in the three countries and shed light on how information about CCS is promoted through the SERP interface influencing how information and knowledge on the topic is made available to the public through Google.

Below, we analyze transversal aspects of the CCS results page, including information boxes, search alternatives, and advertisements. We then provide a brief summary of the results for each country separately. Finally, we compare the results from the different countries and highlight important aspects of how Google search engines shape the information accessible on the internet when users search for Carbon Capture and Storage.

4. Results

4.1 Information boxes, search alternatives and advertisements

When searching for CCS in the three countries Google provides several alternative suggestions both when typing words into the search box and, after the search, at the bottom of the results page in the “People also searched” section. In the case of CCS suggestions, we found that they do not differ much between countries or queries.

In Portugal, for example, when searching for CCS in Portuguese on google.pt, the platform suggests several alternative search terms, related to CCS in Brazil, CCUS (carbon capture utilization and storage), CSS (carbon capture and sequestration), bioenergy, and, as the last

option, problems associated with CCS. At the bottom of the page, in the “People also searched” section, Google also suggests alternative queries. These are similar, but they also include specific phrases or questions, like “measures that can contribute to CO₂ reduction” and “what you need to do to decrease your concentration of CO₂”.

The same happens in France and Spain. Most of the suggested alternative searches are quite generic and often related to other types of carbon sequestration. Some are more specific to the national context, like the one on “CO₂ capture by TotalEnergies” (a French company) on google.fr, and “CO₂ capture and storage in Spain” on google.es.

Google also presents an information box on CCS on the right side of the results page in almost all the queries. In the three countries, this information box includes content from Wikipedia. In Portugal and Spain, the content is extracted from the Portuguese and Spanish CCS pages, respectively, and in France from the more generic page on carbon sequestration. The boxes include a text excerpt from the Wikipedia pages, as well as other photos from Google images. These images mostly show a graphic representation of the technology and have different sources.

When users type search terms into Google, the platform often presents questions on top of the results page. This was the case with CCS searches in France and Spain but not in Portugal. In Portugal, none of the SERPs presented a “people also ask” section, probably due to the fact that in Portugal there is less information available and lower levels of interest in the topic compared to the other two countries (see Düttschke et al., 2022a).

When searching for “CCS” in France on google.fr, the platform suggests several questions to the user: “How to capture carbon?”, “How to capture, store and add value to CO₂?”, “Where is CO₂ stored?”, “How does CO₂ capture function?”. The questions are answered with information from different sources. For example, the question “Where is CO₂ stored?” is answered with a snippet from a Q&A article on CCS from Les Horizon: Media d’intelligence écologique, an online media dedicated to the ecological transition and the climate. The snippet highlights different ways to store CO₂ and makes the connection to the natural carbon cycle.

The same happens in Spain. When searching for Carbon Capture and Storage on www.google.es, on the result page Google suggests the following questions: “How does carbon sequestration take place?”, “What is carbon dioxide capture and storage?”, “How is carbon stored?”, “How does CO₂ capture take place in plants?”. These questions are answered with text snippets from very different websites: a Q&A page on CCS from Energyavm.es (a gas and electricity company from Spain); a post on CCS from Ecologistasenaccion.org (a confederation of more than 300 environmental groups from Spain); the Spanish version of a page on “*Carbon and Climate – Basic information on the major components of the carbon cycle*” from Galenmckinley.github.io project; and a post on the effects of excess CO₂ on plants from Enviraio.es (a company in the development of solutions for monitoring environmental parameters and structural health in industrial, urban and agricultural environments).

The snippets are all very brief and do not give the user a complete reading of the original source. It is also important to notice that, both in France and Spain, when you click on one of the questions, Google quickly adds other questions to the list, making it possible for someone to explore different aspects of CCS technology without leaving the result page.

In the three countries, the results page when searching for the general query on CCS also includes a specific section highlighting videos from YouTube, a Google-affiliated website⁸.

In France, the three videos highlighted are very different from one another. The first one is a short animation film from Canada aimed at a younger audience explaining the carbon capture and storage processes. The second is a long (53m38s) and extensively researched video from a French science influencer YouTube channel. The third video is a very short informative film on CCS created by the global news agency Agence France-Presse (AFP).

In Spain, the three videos highlighted were: the same AFP short film, dubbed in Spanish and shared by AFP Spain YouTube channel; a short video on CCS created and shared by ChemWorld, a channel created by a group of Chemical Engineering students from Peru, and another short informative video from EANOR, a certification of management systems, products and services multinational corporation from Spain.

The Portuguese result page for “CCS” also presented a specific section with videos from YouTube. The videos were posted by different channels, but on close inspection, it became clear that it was the same short film produced by AFP that also appeared in results in the other countries, in this case, dubbed into Brazilian Portuguese.

Finally, in all the countries, despite cleaning cookies and using an incognito window, the result pages ended up displaying an advertisement from a company related to CCS at the end of the page. It is an advertisement for a company that offers services in the CCS field (Geoscience expertise to accelerate the deployment of CCS). This advertisement appeared in English and appears to target anyone searching for CCS in these countries regardless of the language used.

4.2 Results list

Results in France

The list of results obtained when searching for CCS in www.google.fr is quite diverse (Table 1).

Table 1 Google.fr search results (France)

Website	Source	Content	Valuation	Rank search CCS	Rank search CCS risks	Rank search CCS France
energystream-wavestone.com	Private company (consultancy)	Blog article on CCS	Balanced	1	5	1
leshorizons.net	Environmental media	Detailed article on CCS	Balanced	2	6	2
ifpenergiesnouvelles.fr	Public Research institution	Detailed article on CCS	Balanced	3		3
connaissancedesenergies.org	Environmental media connected to an industrial group	Educational sheet on CCS	Balanced/positive	4		9
reporterre.net	Environmental media	Article on CCS	Negative	5		5
ademe.fr	National energy agencies	Informative report on CCS	Balanced	6		6
hellocarbo.com	Private company (specialized on carbon footprint management)	Q&A Blog post on CCS	Balanced	7	4	7
open-diplomacy.eu	Think-tank organization (blog)	Article on CCS	Balanced	8		
fr.wikipedia.org	Wikipedia page	Informative text on carbon sequestration	Balanced	9	9	
actu-environnement.com	Environmental media	News article on CCS (behind paywall)	Negative		1	

journals.openedition.org/vertigo	Academic journal	Academic paper	Neutral		2	
halshs.archives-ouvertes.fr	Academic repository	Academic paper	Neutral		3	
erudit.org	Academic journal	Academic paper	Neutral		7	
centre-cired.fr	Public Research institution	Academic report	Neutral		8	
sortirdunucleaire.org	ENGO	Commentary	Negative		10	
cairn.info	Academic Journal	Scientific paper on political support of CCS in France	Neutral			4
liberation.fr	Media (legacy newspaper)	Detailed article	Negative			8

There are two pages from private companies with extensive information on CCS, a blog post on CCS from the energy blog of Wavestone consultants, and a Q&A article on CCS from the Carbo company, specialized in web solutions for individuals and companies to manage their carbon footprint. None of the articles focus on the company services directly. The first one focuses on the importance and urgency of the technology to fight climate change, as well as its viability. It is a long post that mentions the need for regulation and public subvention, the sensitivity of the subject, and the opposition of NGOs like Greenpeace. The second one from the company Carbo is a long Q&A on CCS that includes information on the technical aspects of CCS, its application in the world, many investments, interest in the technology, energy efficiency, limitation of carbon emissions, circular economy, and reutilization of carbon, mitigation. It also mentions some limitations, namely its costs, uncertain reliability of geological zones, carbon leakage, and the fact that it is not a carbon-neutral technology⁹.

There are also several articles from media platforms. A Q&A article on CCS from “Les Horizon: Media d’intelligence ecologique”; an article from the media website “Connaissance des Énergies” an energy subsidiary of the Alcen industrial group; an article with a critical perspective on CCS from Reporterre, an independent media managed by a non-profit association dedicated to ecology. There is also a link to an informative report from ADEME (national energy agencies) on CCS from 2015, a blogpost on CCS from the website of the think-tank Open Diplomacy working on the global governance of sustainability, and finally the link to the Wikipedia page on Carbon sequestration. Overall, the information from these sources is quite detailed and covers several issues, including benefits and risks, limitations, public investment, as well as projects in development.

When searching for “CCS risks”, www.google.fr presents a featured snippet from the NGO Actu-environnement extracted from an article from 2012 titled “What are the risks of CO2 storage?”. The snippet is not explicit on the risks but indicates that CCS has different types of risks.

In terms of results, the list when searching for “CCS Risks” presents some differences in relation to the general search on “CCS”. There are some repetitions, which are two pages from private companies, in addition to the Q&A article on CCS from the environmental media “Les Horizon” and the Wikipedia page on carbon sequestration. All these pages tend to present a balanced view of CCS, as their content includes information both on CCS benefits and risks.

There are also four links to academic sources. Three of them lead to the same academic paper. The fourth one is a report focusing on the results of a survey on public perception of CCS in France in 2007. The links with the most critical view of CCS are from two environmental media projects. An article published in 2012 by Actu-Environnement, an independent news website specialized in the environment and another one from 2009, published under the section “false alternatives” by the “Revue Sortir du nucléaire”. This article considers that CCS was, at the

time, expensive, and inefficient, and that it does not contribute to the fight against climate change.

Overall, the difference between the search on “CCS” versus “CCS risks” is that in the second case the links have a clearer focus on risks. However, it is also relevant to notice that articles that have a balanced view on CCS can be quite different. In some cases, the negative aspects mentioned are its cost, lack of progress, need for more research, and the fact that it is a sensitive topic for populations. In other cases, the articles also mention environmental risks (leakage, seismic effects, acidification, etc.) and that it incentivizes the continued emission of carbon dioxide¹⁰.

When searching for “CCS France” most of the results were not new and appear repeated from previous searches on “CCS” and “CCS Risks”¹¹. There are only two exceptions. An academic paper that identifies the public policies needed to achieve defined targets in the energy sector, and a detailed news article from 2021 from the newspaper “Liberation”, presenting a rather negative view of CCS.

In total, the four queries we performed resulted in 17 different sources. There were six academic sources, three linking to the same academic paper. Five articles come from online media, mostly from environmental-specialized publications. These media projects, however, have different origins, being either independent, connected to environmental NGOs or private corporations. Only one of the results linked to an article from a traditional legacy media (Liberation). Although only three URLs were from private companies, these were visible, being present in almost all the queries. The Wikipage on carbon sequestration only appeared in one query.

Results in Spain

The list of results for carbon capture and storage on google.es includes pages from very different sources (Table 2). The first one is the CCS page on the Spanish-language Wikipedia, which has an overall negative tone on the technology. There are also five links to pages of private companies. Some of these companies work in the energy and CCS field. Additionally, there is a link to an article on a bank website offering a business perspective on CCS and a webpage with Q&A on CCS from a gas and electricity company. Most of the companies’ sources link to pages with a neutral or positive view on the topic, highlighting its role in emission reduction, its importance in energy transition, fighting climate change, the growing market, and in some cases its development in Spain. When referring to negative aspects, private companies mostly mention the high costs and the need for government support.

Table 2 Google.es search results (Spain)

Website	Source	Content	Valuation	Rank search CCS	Rank search CCS risks	Rank search CCS Spain
es.wikipedia.org	Spanish-language Wikipedia	Wikipage on CCS	Neutral/ Negative	1	8	
energyavm.es	Private company (energy)	Q&A on CCS	Positive	2		
ecologistasenaccion.org	ENGO	Repost of an opinion magazine article	Negative	3	4	10
l2ecogn.com	Private company (energy)	Post on CCUS and the company CO2 initiatives	Positive	4		4
greenfacts.org	Environmental media	Q&A on CCS	Balanced	5	3	

l3ecognize.lamarea.com	Environmental media connected to a newspaper	Repost of a Q&A on CCS from the Ferret fact checking initiative (UK).	Balanced	6		
bbva.com	Private company (banking)	Blog post on CCS	Positive	7		
wsp.com	Private company (consultant)	Post on CCS and the company's work on the topic	Neutral/positive	8		9
osl-iberia.com	Private company (energy)	Webpage on CCS and the company work on the topic	Positive	9		
blog.softtek.com	Private company (digital Technologies)	Blog post on CCS	Positive	10		
evwind.com	Environmental media connected to a renewables association	Article analyzing a published academic study	Negative		1	
foei.org	ENGO	Article on the risks of bioenergy with carbon capture and storage	Negative		2	
retema.es	Environment/technical media	Article about CCS.	Positive		5	
sisbib.unmsm.edu.pe	Academic repository	Academic paper on CCS risk analysis	Neutral		6	
tree-hugger8.net	Environmental media	Article explaining CCS	Balanced		7	
technologyreview.es	Technical media	Article about CCS	Negative		9	
archive.ipcc.ch	International organisation	PDF on CCS Summary report for policy makers.	Balanced		10	
europapress.es	News agency	Article about a scientific study on the current development of CCS in Spain	Positive			1
xataka.com	Technical media	Article about a scientific study on the current development of CCS in Spain	Positive			2
csic.es	Public Research institution	Press release about a scientific study on the current development of CCS in Spain	Positive			3
verdeyazul.diarioinformacion.com	Environmental media connected to a newspaper	Article about a scientific study on the current development of CCS in Spain	Positive			5
elperiodicodelaenergia.com	Environment/technical media	Article about the start of the PilotSTRATEGY project and the participation of Repsol.	Neutral/Positive			6
pteco2.es	Spanish CO2 Technology Platform	Press release about a workshop on CCS in Spain with experts	Neutral			7
efe.com	News agency	Article about a scientific study on the current development of CCS in Spain	Positive			8

There are also links to pages from NGOs: the first one is a post with a reprint of a magazine article with a very negative view on CCS written by an environmentalist in 2013 from the blog of an environmental association. The second link is to a page with information on CCS from project GreenFacts, a non-profit organization with a mission to present clear and factual summaries of complex scientific reports on health and the environment to non-specialists. The

first link presents a clear negative view of CCS. The second link is an information sheet containing Q&A on CCS. Additionally, there is a link to an article on CCS from a climate change-specialized magazine, which was translated from the fact-checking project The Ferret. On the other hand, when searching for “CCS Risks” another featured snippet is shown. In this case, the snippet is from a 2010 post from the REVE, summarizing a paper on CCS risk from Nature Geoscience. The article is quite critical of CCS, with the snippet highlighting the risk of ocean acidification.

The list of sources presented by Google on the results page when searching for “CCS risks” in Spanish is different from a general search for “CCS” and includes several posts and articles that are quite critical of CCS. For example, there is an article from the website of the environmental association “Friends of the Earth International”, which highlights a report that considers CCS a distraction, risky, expensive, and dangerous. The posts promoted by Ecologistas en Acción emphasize the economic impracticality, risks, and costs of CCS. The article from the MIT Technical Review, mentions how expensive and energy-intensive the technology is and how it could divert investments from renewable energies.

The other URLs present either a more balanced view on the technology (like the report on CCS from IPCC, presenting both the risks and benefits of the technology), or they actively downplay the risks of CCS (like the article from Retema, which minimizes the risks of leaks and highlights the need to act).

It is relevant to notice that 5 of the 10 links promoted by Google when searching for CCS Spain have similar content. They all result from a press release from CSIC (Consejo Superior de Investigaciones Científicas) about a study conducted by both CSIC and the University of Barcelona, and they all mention the possibility that Spain could reduce its annual emissions by 21% with CCS. The actual press release is presented in the 3rd place.

The other links are either web pages on CCS from private companies working in the field or related to research on CCS field articles. The last link on the results page is the post from “Ecologistas en Acción” with a reprint of a magazine article from 2013 that presents a critical perspective on CCS.

In total, the four queries we performed resulted in 24 different sources. Most of them were articles from online media (11), of which seven specialized in environmental issues. Six were websites of private companies, two were from NGOs, and only two were from academic sources. The sources promoted tended to differ depending on the keywords used in the queries, more than in the other countries. This is particularly evident in the query CCS risks which returned results that are quite critical of CCS. Nevertheless, there are some sources that are repeated and appear in more than one keyword combination search.

Results in Portugal

When searching for Carbon Capture and Storage the list of results promoted by google.pt on the first page is relatively diverse (Table 3).

Table 3 Google.pt search results (Portugal)

Website	Source	Content	Valuation	Rank search CCS	Rank search CCS risks	Rank search CCS Portugal
ecycle.com.br	Private company (sustainability)	Q&A article on CCS	Balanced	1	1	
pt.wikipedia.org	Portuguese-language Wikipedia	Wikipage on CCS	Neutral	2	9	

veolia.pt	Private company (energy)	Blog post on CCS and the company's work	Positive	3	3	3
jornal.usp.br	Academic newspaper	Page introducing a podcast on CCS	Positive	4		
linde-gas.pt	Private company (energy)	webpage on CCS and the company's work	Positive	5	8	5
run.unl.pt	Academic repository	Master thesis on CCS	Neutral	6	2	6
welltec.com	Private company (energy)	webpage on CCS and the company's products	Neutral/positive	7		
hids.unicamp.br	University	Blogpost on classes on CCS	Positive	8	4	
news.un.org/pt	International organization	Post on a UN commission study on the urgency and benefits of CCS	Positive	9		
wribrasil.org.br	Private research institution	Large article about soil carbon capture.	Not about CCS		5	
goldenergy.pt	Private company (energy)	Short glossary entry	Balanced		6	
dgeg.gov.pt	Government agency (energy)	Page with information on the legal framework and CCS projects in Portugal.	Neutral		7	1
ivar.azores.gov.pt	Public research institution	Repost of a BBC news article about CCS in Iceland	Neutral		10	
icterra.pt	University research institution	Post about the Project STRATEGY CCUS	Positive			2
dspace.uevora.pt	Academic repository	Link to the "CCS roadmap' in Portugal	Positive			4
bcsdportugal.org	Business association	Flyer on CCS from 2006	Balanced			7
ria.ua.pt	Academic repository	Master thesis on CCS	Neutral			8
ulusofona.pt	University	Webpage on an open course on CCS	Neutral/positive			9

The results include the Wikipedia page on CCS, pages from private company websites, academic blogs, theses, and UN News related to the topic. Wikipedia is consistently promoted on the first page. The private companies listed fall into two categories: those working in the

CCS field and eco-companies with Q&A pages that tend to be promoted by Google when searching for specific topics or questions. The academic sources vary, including a Brazilian academic podcast with two CCS experts, a Portuguese university repository housing a Master thesis on CCS; and a page for a CCUS course from a Brazilian university.

In terms of content, all the pages have either a positive or balanced view on CCS. The first promoted page is a Q&A page from a Brazilian eco-company, providing the definition of CCS, along with information on its risks and benefits. Notably, half of the promoted sources are from Brazil, including the one presented in the first place.

The main difference between the results of the search for “CCS” and the results of the search for “CCS risks” is that, in the second case, the page includes highlight snippets from the page titled “*What is Carbon Capture and Storage?*” from the same Brazilian eco-company, focusing on the part of the text that mentions the risks of earthquakes and leaks.

However, the list of results was not significantly different from the one obtained when searching for “CCS”. When searching for “CCS Risks” many of the links on the first pages are the same, although they appear in a different order. There are also a few new entries with a neutral or balanced position on CCS. The results did not include sources with a negative stance towards the technology.

When searching for “CCS Portugal”, Google did not promote any specific question and answer on the page. The list of results includes several of the same URLs present in the general search for CCS, but there are some differences, with the number of Portuguese academic sources increasing significantly. The first link is to a page on Geological Storage of Carbon Dioxide from the website of the governmental agency in charge of energy and geology. This page includes information on the legal framework of CCS in Portugal, as well as a list of projects currently under development. The second listed page is a post from Évora University about the project STRATEGY CCUS. The other pages are from university repositories (linking to reports or master theses on the topic of CCS), two pages on CCS from energy companies working in the field of CCS, a page from the corporate association sharing a flyer from 2006 on CCS, and the page of the course on CCS at a university.

In total, the four queries we performed resulted in 18 different sources. Most of these sources consisted of academic-related content, such as theses on CCS, posts and news related to CCS and CCS research projects, and information on CCS courses (nine), followed by web pages or blog posts from private companies (six). The results did not include any content produced by Portuguese NGOs, environmental media, or legacy media. However, it included several foreign sources (from Brazil)¹².

5. Discussion and conclusion

Our analysis highlights the influence of both local dynamics and Google's search engine ranking criteria on the information available to the public regarding CCS on the internet. In the first case interest and investment in the topic at the national level seem to play a central role (Cano-Orón, 2019). This is reflected in the diversity of actors and types of content, as well as the depth and quality of the information available in the promoted sources.

In France, the results included more balanced perspectives on the topic, different points of view, and in the case of video content, material directed at specific audiences. The results also encompassed academic papers and articles from several online media initiatives related to the environment, either independent or connected to environmental NGOs or private corporations.

In Spain, the results were more diversified, with some of the queries yielding quite different outputs. Most of the results were from environmental online media, some being reposts/translations of articles on CCS written in other projects or countries. Private corporations and NGOs were well-represented, while academic sources had a lower presence. Notably, it was the country where the search for “CCS risk” resulted in a higher number of critical articles on the technology, mostly written or promoted by NGOs or specialized environmental online media.

In Portugal, the available information on CCS appeared to be less diversified compared to Spain and France. This is apparent in the high representation of academic sources in the results list, as well as the presence of web pages with limited informative content. The results also included a higher number of foreign sources, focusing, for example, on information about courses, research, and post-graduate courses in Brazil¹³. Strikingly, there were no results from NGOs or specialized environmental media, distinguishing Portugal's results apart from the other two countries.

Our analysis reveals that the results obtained from the different queries exhibit both similarities and differences. Search results for “CCS risks” and “CCS [name of the country]” tend to be more specific than the general search on “CCS”. The “CCS risks” query results include more sources that present either a critical (Spain) or balanced (Portugal) view of CCS. Furthermore, when searching for 'CCS risks' in France or 'CCS Portugal', there was a greater presence of academic sources compared to other queries.

Wikipedia pages on the topic of CCS are often presented and highlighted with an information box on the right side of the SERP when searching for CCS. This visibility given to Wikipedia pages is relevant for topics like CCS, where there might be limited public awareness, as Wikipedia might act as an introductory reference point for individuals seeking to learn about the subject. As noted in a previous analysis (Prades et al., 2022), Wikipedia pages on CCS in the three national languages of these countries exhibit substantial variations in content. The page in French is the most detailed, although certain sections are not up to date. The page in Portuguese is more recent and considerably shorter, while the page in Spanish is characterized by fragmentation and a lack of coherence. The active promotion of Wikipedia by Google (see also McMahan et al., 2017), therefore, has varying effects on the quality of information that the general population can access when searching for CCS in the three countries.

One noteworthy observation is that apart from an opinion article from the weekly newspaper *Liberation* resulting from one of the queries in France, the results list did not include any article on CCS from major newspapers. This is despite the fact several articles on CCS have been published in the media in the three countries during the previous decade (Prades et al. 2022)¹⁴. This finding differs from results obtained in other comparative analyses that highlighted the presence of mass media-produced content in the search results (Cano-Orón, 2019; Toepfl et al., 2022). Instead, in the case of CCS, the platform seemed to give more visibility to articles published on online specialized media.

In addition to the information boxes, Google highlights some sources in the section “People also ask” and featured snippets by presenting information extracted from them directly on the SERP page (Iliadis, 2022). These sources appear to be selected based on how well Google matches content to the specific query, often presenting information in the form of Q&A¹⁵. From the perspective of the public, this means that when searching for the topic of CCS they are confronted with information directly on Google’s result page that is often short and decontextualized.

Private corporations were among the most visible actors in Google search results, consistently appearing across different queries. This observation aligns with findings from Eklöf & Mager (2013), which highlights how large, well-connected actors are often favored on Google SERP at the expense of others. We identified two main types of private corporations promoting information on CCS: companies directly involved with CCS and companies in the environmental/sustainability field, but not directly related to CCS. These companies typically have SEO-optimized websites that often feature a knowledge base section covering various environmental topics, presented in the form of Q&A.

Our analysis also indicates that the format of some of the results on the first SERP is broadly in line with Google's SEO guidelines. In the top results promoted in the three countries, we found several web pages and blog posts using typified formats and promoting similar content. These semantically embedded formats can be viewed as specific types of rhetorical genres, which influence how communicative acts on the internet are created, shared, recognized, and received (Brannon et al., 2022).

Google's SEO guidelines explicitly outline the norms for constructing Q&A webpages that can be recognized by the search engine. This includes following rhetorical norms for paragraph writing and using specific semantic HTML. As explained by Brannon et al. (2022), genre conventions often serve as templates to achieve specific goals. In the realm of search engines, the primary goal of using these genres is to be recognized as relevant by the platform, thereby gaining visibility for a website or brand. This process tends to prioritize information produced in generic Q&A formats designed to be recognized by Google's algorithms.

Due to this prioritization content producers not directly related to the searched issues may be promoted and pages exhibiting striking similarities despite originating from different sources may be presented. As a result, it becomes increasingly challenging for users to contextualize the origin and quality of information they access when searching for a topic like CCS- a risk that is further amplified by Google's increased reliance on suggested questions and snippets (Iliadis, 2022).

In conclusion, Google's presentation and prioritization of information holds considerable significance for the formation and dissemination of knowledge, particularly on a topic like CCS, which is still relatively unfamiliar to the public. It not only impacts the accessibility and comprehensiveness of information but also shapes the type of content available on the subject. The interplay between Google, content producers, and other media co-creates a specific logic of knowledge production (Haider & Rödl, 2023), resulting in varying implications at the national level. These processes offer valuable insights into the mediating role of search engines as they promote specific sources and content across different national contexts, thereby shaping how the public accesses information about emergent climate change technologies.

Acknowledgments

This article was written in the context of the project PilotSTRATEGY, which was funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101022664. The authors would like to express their gratitude to their project colleagues for their support and insights. Additionally, the authors extend their appreciation to the anonymous reviewers for their generous and constructive feedback, which greatly helped in improving this paper.

References

- Andersen, J. (2008). The concept of genre in information studies. *Annual Review of Information Science and Technology*, 42(1), 339–367. <https://doi.org/10.1002/aris.2008.1440420115>
- Ashworth, P., Wade, S., Reiner, D., & Liang, X. (2015). Developments in public communications on CCS. *International Journal of Greenhouse Gas Control*, 40, 449-458.
- Brannon, B., Buhler, A. G., Cataldo, T. T., Faniel, I. M., Connaway, L. S., Valenza, J. K., & Cyr, C. (2022). Genre containers: Building a theoretical framework for studying formats in information behavior. *Journal of the Association for Information Science and Technology*, 73(4), 609–624. <https://doi.org/10.1002/asi.24600>
- Braun, C. (2017). Not in My Backyard: CCS Sites and Public Perception of CCS. *Risk Analysis*, 37(12), 2264–2275. <https://doi.org/10.1111/risa.12793>
- Brunsting, Suzanne, Mastop, J., Kaiser, M., Zimmer, R., Shackley, S., Mabon, L., & Howell, R. (2015). CCS Acceptability: Social Site Characterization and Advancing Awareness at Prospective Storage Sites in Poland and Scotland. *Oil and Gas Science and Technology*, 70(4), 767–784. <https://doi.org/10.2516/ogst/2014024>
- Budinis, S., Krevor, S., Mac Dowell, N., Brandon, N., & Hawkes, A. (2018). An assessment of CCS costs, barriers and potential. *Energy strategy reviews*, 22, 61-81.
- Buhr, K., Hansson, A., 2011. Capturing the stories of corporations: A comparison of media debates on carbon capture and storage in Norway and Sweden. *Global Environ. Change* 21 (2), 336–345.
- Cano-Orón, L. (2019). Dr. Google, what can you tell me about homeopathy? Comparative study of the top10 websites in the United States, United Kingdom, France, Mexico and Spain. *Profesional de La Información*, 28(2), Art. 2. <https://doi.org/10.3145/epi.2019.mar.13>
- Carton, W., Asiyani, A., Beck, S., Buck, H. J., & Lund, J. F. (2020). Negative emissions and the long history of carbon removal. *Wiley Interdisciplinary Reviews: Climate Change*, 11(6), e671.
- Dowd, A. M., Boughen, N., Ashworth, P., & Carr-Cornish, S. (2011). Geothermal technology in Australia: Investigating social acceptance. *Energy policy*, 39(10), 6301-6307.
- Dütschke, E. et al. (2022a). Community Acceptance: Findings from community profiles and first local survey. PilotSTRATEGY. Accessed at: https://pilotstrategy.eu/sites/default/files/2022-11/PilotSTRATEGY%20Deliverable%206-2-final_211122_clean.pdf

- Dütschke, E., et al. (2022b). Engaging the Public with CCUS: Reflection on a European Project Approach. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4284094>
- Eklöf, J., & Mager, A. (2013). Technoscientific promotion and biofuel policy: How the press and search engines stage the biofuel controversy. *Media, Culture & Society*, 35(4), 454–471. <https://doi.org/10.1177/0163443713483794>
- Gerhart, S. (2004). Do Web search engines suppress controversy?. *First Monday*.
- Giomelakis, D., Karypidou, C., & Veglis, A. (2019). SEO inside Newsrooms: Reports from the Field. *Future Internet*, 11(12), Art. 12. <https://doi.org/10.3390/fi11120261>
- Google (no date), Understand how structured data markup works, <https://developers.google.com/search/docs/appearance/structured-data/intro-structured-data>, Retrieved 11/30/2022
- Ha-Duong, M., Nadaï, A., & Campos, A. S. (2009). A survey on the public perception of CCS in France. *International Journal of Greenhouse Gas Control*, 3(5), 633–640. <https://doi.org/10.1016/j.ijggc.2009.05.003>
- Haider, J. (2016). The structuring of information through search: Sorting waste with Google. *Aslib Journal of Information Management*, 68(4), 390–406. <https://doi.org/10.1108/AJIM-12-2015-0189>
- Haider, J., & Rödl, M. (2023). Google Search and the creation of ignorance: The case of the climate crisis. *Big Data & Society*, 10(1), 20539517231158997. <https://doi.org/10.1177/20539517231158997>
- Haider, J., & Sundin, O. (2019). *Invisible Search and Online Search Engines: The Ubiquity of Search in Everyday Life* (1.^a ed.). Routledge. <https://doi.org/10.4324/9780429448546>
- Höchstötter, N., & Lewandowski, D. (2009). What users see – Structures in search engine results pages. *Information Sciences*, 179(12), 1796–1812. <https://doi.org/10.1016/j.ins.2009.01.028>
- Iliadis, A. (2022). *Semantic Media: Mapping Meaning on the Internet*. John Wiley & Sons.
- IPCC Working Group III. (2022). *Climate Change 2022-Mitigation of Climate Change: Summary for Policymakers*. Intergovernmental Panel on Climate Change.
- Itaoka, K., Dowd, A. M., Saito, A., Paukovic, M., de Best-Waldhober, M., & Ashworth, P. (2013). Relating individual perceptions of carbon dioxide to perceptions of CCS: an international comparative study. *Energy Procedia*, 37, 7436-7443.
- Karimi, F. (2017) Timescapes of CCS projects: is deferring projects and policies just kicking the can down the road?. *Energy Procedia*, 114 (2017), pp. 7317-7325
- Kuijper, I. M. (2011). Public acceptance challenges for onshore CO2 storage in Barendrecht. *Energy Procedia*, 4, 6226-6233.
- Lewandowski, D., & Schultheiß, S. (2022). Public awareness and attitudes towards search engine optimization. *Behaviour & Information Technology*, 1–20. <https://doi.org/10.1080/0144929X.2022.2056507>

- Lewandowski, D., Sünkler, S., & Yagci, N. (2021). The influence of search engine optimization on Google's results: A multi-dimensional approach for detecting SEO. *13th ACM Web Science Conference 2021*, 12–20. <https://doi.org/10.1145/3447535.3462479>
- Li, K., Lin, M., Lin, Z., & Xing, B. (2014). Running and Chasing – The Competition between Paid Search Marketing and Search Engine Optimization. *2014 47th Hawaii International Conference on System Sciences*, 3110–3119. <https://doi.org/10.1109/HICSS.2014.640>
- Lipponen, J., McCulloch, S., Keeling, S., Stanley, T., Berghout, N., & Berly, T. (2017). The politics of large-scale CCS deployment. *Energy Procedia*, 114, 7581-7595.
- Lofstedt, R. (2015) Effective risk communication and CCS: the road to success in Europe, *Journal of Risk Research*, 18:6, 675-691
- McMahon, C., Johnson, I., & Hecht, B. (2017). The Substantial Interdependence of Wikipedia and Google: A Case Study on the Relationship Between Peer Production Communities and Information Technologies. 10.
- Metaxa, D., Park, J. S., Robertson, R. E., Karahalios, K., Wilson, C., Hancock, J., & Sandvig, C. (2021). Auditing Algorithms: Understanding Algorithmic Systems from the Outside In. *Foundations and Trends® in Human-Computer Interaction*, 14(4), 272–344. <https://doi.org/10.1561/11000000083>
- Mustafaraj, E., Lurie, E., & Devine, C. (2020). The case for voter-centered audits of search engines during political elections. *Proceedings of the 2020 Conference on Fairness, Accountability, and Transparency*, 559–569. <https://doi.org/10.1145/3351095.3372835>
- Oltra, C. Sala, R. Solà, M. Di Masso, G. Rowe (2010), Lay perceptions of carbon capture and storage technology, *Int. J. Greenh. Gas Contr.*, 4 (4), pp. 698-706
- Oltra C., Upham P, Riesch H, et al. (2012) Public Responses to CO2 Storage Sites: Lessons from Five European Cases. *Energy & environment*, 2012;23(2&3):227–48.
- Oltra, C., Delicado, A., Prades, A., Pereira, S., & Schmidt, L. (2014). The Holy Grail of energy? A content and thematic analysis of the presentation of nuclear fusion on the Internet. *Journal of Science Communication*, 13.
- Otto, D., Pfeiffer, M., de Brito, M. M., & Gross, M. (2022). Fixed Amidst Change: 20 Years of Media Coverage on Carbon Capture and Storage in Germany. *Sustainability*, 14(12), 7342.
- Pires, J. C. M., Martins, F. G., Alvim-Ferraz, M. C. M., & Simões, M. (2011). Recent developments on carbon capture and storage: An overview. *Chemical engineering research and design*, 89(9), 1446-1460.
- Prades, A. et al. (2022), Annex 1. Media Analysis, PilotSTRATEGY. Accessed at: <https://pilotstrategy.eu/sites/default/files/2022-11/Annex%201%20Media%20Analysis%20Report.pdf>.
- Shackley, S., Deutschke, E., Dowd, A.-M., Ashworth, P., Rodriguez, M., Jeanneret, T., 2012. CCS in the Media: an analysis of international coverage. *Energy Environment*, 23 (2–3), 283–298.

Schultheiß, S., & Lewandowski, D. (2021). Misplaced trust? The relationship between trust, ability to identify commercially influenced results and search engine preference. *Journal of Information Science*, 016555152110141. <https://doi.org/10.1177/01655515211014157>

StatCounter (2022). Search engine market share <https://gs.statcounter.com/> (accessed 23 November 2022).

Sundin, O., Lewandowski, D., & Haider, J. (2021). Whose relevance? Web search engines as multisided relevance machines. *Journal of the Association for Information Science and Technology*, asi.24570. <https://doi.org/10.1002/asi.24570>

Tcvetkov, P., Cherepovitsyn, A., & Fedoseev, S. (2019). Public perception of carbon capture and storage: A state-of-the-art overview. *Heliyon*, 5(12), e02845.

Toepfl, F., Kravets, D., Ryzhova, A., & Beseler, A. (2022). Who are the plotters behind the pandemic? Comparing Covid-19 conspiracy theories in Google search results across five key target countries of Russia's foreign communication. *Information, Communication & Society*, 0(0), 1–19. <https://doi.org/10.1080/1369118X.2022.2065213>

Tripodi, F. (2018). Searching for Alternative Facts: Analyzing Scriptural Inference in Conservative News Practices. *Data & Society*. https://datasociety.net/wp-content/uploads/2018/05/Data_Society_Searching-for-Alternative-Facts.pdf

Tripodi, F. B. (2022). *The Propagandists' Playbook: How Conservative Elites Manipulate Search and Threaten Democracy*. Yale University Press.

Ulloa, R., Makhortykh, M., & Urman, A. (2022). Scaling up search engine audits: Practical insights for algorithm auditing. *Journal of Information Science*, 01655515221093029. <https://doi.org/10.1177/01655515221093029>

Vercelli, S.J. Anderlucci, R. Memoli, N. Battisti, L. Mabon, S. Lombardi (2013), Informing people about CCS: a review of social research studies. *Energy Procedia*, 37, pp. 7464-7473

¹ This article stems from a research project funded by the European Commission, PilotSTRATEGY (2021-2026), which aims to enable these countries to start developing their carbon storage resources by integrating geological, technical and economic research with social sciences (Dütschke et al., 2022b). This article is partially based on a project report (Dütschke et al., 2022a; Prades et al. 2022).

² We refer to queries based on general search terms to differentiate them from "naturalistic" queries, which are formulated based on an understanding of the most commonly used search terms by individuals seeking information on the topic (see Mustafaraj et al. 2020; Tripodi, 2018, 2022).

³ We specifically chose the term "risk" to explore the general information related to the negative socio-technical implications associated with the technology as promoted on Google SERP. It is important to note that we did not include queries about specific risks, which are commonly discussed in relation to CCS, such as seismic risk or CO₂ leakage.

⁴ In the original report (Prades et al. 2022), there was a fourth query focused on the benefits of CCS. However, it was found that the results did not significantly differ from the general

CCS query. Due to space constraints and to maintain a focus, the benefits query was excluded from this article.

⁵ We use the term “CCS”; “CCS risks”, and “CCS France/Spain/Portugal”, respectively.

⁶ Oltra et al. (2014) use the term “ambivalent” to describe sources that combine positive and negative arguments towards the technology. In this article, we opted to use the term “balanced” to express the same ideas to align with the terminology used to classify press articles on CCS in our original report (Prades et al., 2022). The quality of the arguments presented in the sources was not taken into consideration.

⁷ We use the term “neutral” to describe sources that do not present positive or negative arguments towards CCS. Mostly sources that discuss technical aspects of the technology or describe events or courses.

⁸ YouTube is a subsidiary of Alphabet Inc. which is the parent company of Google.

⁹ CCS has been criticized because it requires significant energy inputs, both on capture, transporting and storing processes. Critics argue that the energy penalty associated with CCS may outweigh the emission reduction benefits, especially if cleaner and more efficient energy alternatives are available (Budinis et al., 2018)

¹⁰ Although some companies tend to focus on the first type of negative arguments of CCS, there are exceptions, and with such a small sample of articles that tend to be quite hybrid in terms of format and origin, it is not possible to make any clear connection between sources and arguments.

¹¹ This is in contrast to Spain and Portugal where the search results for a query including the name of the country were different from the general search on CCS. This mostly highlights differences in the information available on CCS in the online public sphere, with France having more information available on CCS and specifically CCS within France.

¹² Some of the results in France and Spain included international sources. However, these were mostly websites with general content on CCS suitable for an international audience. In contrast, the results in Portugal included several Brazilian sources that were more specific providing, for example, information about courses, and post-graduations available in Brazil.

¹³ Due to the large amount of content on the internet from Brazil versus content from Portugal, it is not unusual for Google to suggest results from Brazil for people searching for content in Portugal, especially in topics with less information available in Portugal. See for example the answers provided to a question related to this issue in the Google Search Help Community where one of the experts explains that it is probably “because the number of results that the search considers relevant in Brazilian Portuguese is much higher than the results in Portuguese from Portugal”:

<https://support.google.com/websearch/thread/188301049/porque-%C3%A9-que-a-maioria-dos-resultados-das-minhas-pesquisas-me-apresenta-sites-brasileiros?hl=pt-BR>

¹⁴ Although the media analysis performed showed that CCS has generally a relatively low expression in the current public debate in the press in the three countries, the topic is not completely absent. In a 10-year period (2011-2021), the analysis of a selection of newspapers at the national, regional, and local levels, resulted in a total of 267 newspaper articles on the topic: 97 in Spain, 129 in France and 52 in Portugal (Prades et al., 2022)

¹⁵ By checking the HTML code of the pages, we have also confirmed that all highlighted sources make use of SEO and analytic tools that are typically employed in SEO context (Lewandowski et al., 2021). The most commonly used tools were Google Analytics and the Yoast SEO plugin.