Media Framing of CCUS, CCU, and CCS in North America, Europe, and the Middle East from 2020-2025

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Abstract

Carbon capture, utilisation, and storage (CCUS) technologies are projected to play a crucial role in decarbonisation as 2050 net-zero targets are approached. Successful deployment, however, is dependent on public perception and acceptance. Such aspects are influenced by how media publications frame the discourse on the discussed technologies. By analysing media, the way in which the public perceives a technology can be uncovered. In this research, the main objective is to explore media framing of CCUS, carbon capture & utilisation (CCU), and carbon capture & storage (CCS) from an international perspective. The chosen media type, newspapers, is studied in three regions: the Middle East, Europe, and North America. Additional aims are to determine the dominant frame in each region and to see if there is a difference in framing between CCUS, CCU, and CCS. This is investigated with two methods, quantitative content analysis and media frame analysis. 100 articles per region are obtained from the Nexis Uni database and manually coded using a pre-existing framework, the Socio-Political Evaluation of Energy Deployment (SPEED) framework.

The environmental and economic frames are found to be the most common in all three regions. In North America and Europe, the technical and regulatory & legal frames are also a frequent point of discussion. Among such frames in North America and Europe, benefit framing is the most common. Approximately 53% and 68% of the references are framed as benefits in North America and Europe respectively. However, a significant portion of risk framing is present for the studied SPEED frames in both regions, indicating that public perception is mixed. Contrarily, for Middle Eastern articles, nearly all references are comprised of environmental framing (67%), and economic framing (29%). Furthermore, 90% of references in Middle Eastern articles are described as benefits. Differences in framing between CCUS, CCU, and CCS are difficult to discern, perhaps due to the unclear distinction of terminology present in North American and European articles. However, findings suggest that CCUS and CCS are mentioned more frequently than CCU in all regions.

1 Introduction

1.1 CCUS Background

The past ten years have been the warmest on record, with 2024 being 1.55°C above pre-industrial levels [1]. As the planet continues to experience an increase in temperature, the pressure to transition to more sustainable energy sources is becoming increasingly important [1]. Part of the solution to curbing this temperature increase requires meeting the 2050 net-zero greenhouse gas (GHG) emission goals set by the European Commission and the 2015 Paris Agreement [2] [3]. The success of these goals will predominantly depend on the swift transition to green electrification and other sustainable energy alternatives (e.g., bioenergy, hydrogen) [4]. However, implementing such solutions is not enough to achieve the necessary CO_2 emission reductions.

This can be attributed to the emissions caused by high-emitting industries (e.g. iron & steel, cement, magnesium), which are the second largest source of CO_2 emissions and represent 40% of the final energy consumption in 2017 [4]. These industries are highly valuable to the EU economy, but are difficult to abate. This is because renewable energy cannot eliminate all CO_2 emissions. Cement production, for example, requires the calcination of limestone, in which the CO_2 emissions are derived from the process rather than the energy used, and thus are impossible to eliminate [4]. Furthermore, such industries require high temperatures for all their processes (e.g. 1600°C). Using green energy to remove emissions from high-temperature processes is often economically infeasible or difficult to implement [5]. To successfully abate unavoidable emissions, industries will depend on the implementation of carbon capture, utilisation, and storage (CCUS) technologies.

According to the International Energy Agency (IEA), CCUS is defined as the process of capturing CO_2 from a point source or air, followed by the valorisation of CO_2 and/or storage [6]. CCUS can also be seen as an umbrella term, encompassing the technologies carbon capture & storage (CCS) and carbon capture & utilisation (CCU). CCUS technologies are critical to emission reduction plans for sectors with unavoidable emissions. With this technology, high-emitting sectors will be able to continue operating while working towards the 2050 net-zero GHG targets, thus benefiting the environment and economy [5]. Another notable benefit is achieved through the utilisation aspect. CO_2 can be a chemical precursor for a wide range of products that are typically made with virgin fossil fuels, including but not limited to plastics, minerals, and methanol [7]. In this sense, CCUS can simultaneously reduce upstream emissions and contribute to a circular economy [8]. When implemented dually with green electrification, there is a potential for the technology to help facilitate a quicker sustainable transition [4].

1.2 The ConcenCUS Project and Problem Definition

This thesis takes place at the New Energy Coalition as part of the ConcenCUS project, which is funded by the Horizon Europe programme. The ConcenCUS project has the aim of contributing to a net-zero future through the development of electricity-based innovations in CCUS [9]. Such innovations include the use of renewable energy in the capture unit, which reduces the emissions of the capturing process and produces a pure CO_2 stream from flue gas [9]. Furthermore, the ConcenCUS project also aims to plan for net-zero industry clusters, where multiple CO_2 emitters, storage locations, and utilisation sites can be brought together with shared infrastructure and knowledge systems to help lower the cost of the technology. All of this will accumulate into a net-zero carbon framework, which simultaneously aims to reduce the impact of the technical, economic, and environmental aspects, while also finding ways to integrate local communities in areas with such clusters.

Public perception of CCUS technologies are going to play a critical role for CCUS developments due to the controversies surrounding CCUS. These consist mainly of safety concerns regarding transport and storage of CO_2, which can induce strong public opposition [10]. Understanding public perception is important, as the attitudes reflected play a key role in policy-making and the success of a technology [11][10]. If there is a lack of public acceptance, there is a higher risk of project suspensions; on the contrary, if more positive attitudes are present, the development of a technology can accelerate [12] [10]. Having a detailed understanding of public attitudes on CCUS is valuable in helping policymakers and those involved with the technical aspects properly take into account concerns, thus ensuring a smoother implementation [13].

1.3 Research Aim

There is extensive literature present on public perception of CCU, CCS, and CCUS, in which most studies focused on a singular country as a case study and used surveys to gather public opinion on CCUS technologies [13][14][15][10][16][17][18]. The results of these studies vary, but highlight that CCU is viewed in a more positive light compared to CCS and that there is a general lack of understanding of CCUS technologies as a whole. However, there are few studies present that take an international perspective into account and compare how the media frames CCUS technologies between multiple regions. Such an approach could be highly valuable to the ConcenCUS project, as the study of international public perception of CCUS is a key objective of the project. Studying differences in media frames of CCUS, CCU, and CCS could also help gain an understanding of the most dominant public concerns and whether these differ depending on the end-use of CO_2. As such, the following research questions were developed to guide this study:

1. How does media framing of CCUS, CCU, and CCS vary in North America, Europe, and the Middle East from 2020-2025?
   (a) Which frame is most common amongst all regions?
   (b) Is there a difference in framing between regions?
   (c) Is there a difference in framing between CCUS, CCU, and CCS?

2 Materials & Methods

2.1 Literature Review

A synoptic literature review is conducted for this study to provide background on previous CCUS public acceptance research and to investigate the relevance of the Social-Political Evaluation of Energy Deployment (SPEED) framework for use in the media frame analysis (*See section 2.2 for details of SPEED*). Articles are chosen through citation chaining of articles found in Google Scholar, including other literature reviews (e.g. Zuch and Ladenburg [19]). References with titles related to search terms "CCU", "CCS", "CCUS", "Public acceptance", and "Public perception" are chosen and subsequently utilised to gather more articles. From this process, 21 articles are selected for the review (see attached document **S1** in supporting information for the full list of references used).

Out of the 21 articles, most articles discuss CCUS technologies in the context of Europe (42%), followed by North America (19%). A sizeable portion of articles (14%) discussed public perception and acceptance of CCUS in East and South-East Asia. Other articles either take an international perspective or are literature reviews. Most articles use a survey approach, both offline and online, to investigate public perception (for example, [20][21][22][23]). However, four of the 21 articles analysed media portrayals of CCUS technologies, either through discourse analysis, media frame analysis, or media content analysis. Of these articles, most use two main frames for analysis: "risk" and "benefit", or "enthusiastic" and "critical" [15][14][18]. However, Wædegaard et al. [15] and Feldpausch-Parker et al. [18] perform their frame analysis with frames derived from the SPEED framework.

2.1.1 Comparison of Public Perception CCU, CCUS, and CCS

In the reviewed articles, it is evident that there is a general rejection of CCS and CCUS technologies from the public, mainly due to the perceived risks of implementation. These risks typically take the form of safety concerns regarding the storage and transport of CO_2 [24][13][25][26]. Concerns for the high cost of CCUS technologies are also present, as well as a fear that it will reduce motivation to emit less CO_2 [26] [10]. Additionally, there appears to be a spatial component that impacts the perceived risk of CCS. For example, using an online survey directed to the Swiss public, Dallo et al. [26] finds that there is lower acceptance of CCUS if the CO_2 is stored locally. A similar conclusion is noted in Midden and Huijts [21], which finds via a paper questionnaire that residents in the Netherlands feel more negative towards the idea of CCS near their homes, mainly due to distrust. Perceived benefits, like the creation of jobs, are present, but not as frequently mentioned in articles. However, Tokushige et al. [20] finds that a positive influence on the storage of CO_2 is seen when discussed in the context of global warming and climate change.

In the case of CCU, these concerns are not present. CCU appears to be seen more favourably by the public, as a technology that can create jobs and improve air quality [25]. A similar sentiment is portrayed in a framing analysis conducted by Fürst and Strunge [14] in Germany, which finds that CCU is presented as a technology that contributes dually to economic growth and reaching Germany's climate goals. CCU is also seen as a way to reduce dependence on virgin fossil resources while simultaneously conserving them [13]. It should be noted that concerns are present for CCU, some regarding CO_2 leakage of CCU products as well as the eventual release of CO_2 later on in the product's life cycle [13][25]. However, it is generally portrayed as a beneficial technology by the public and media [13][25].

2.1.2 Awareness of CCUS Technologies

Another key theme present is a general lack of awareness of what CCUS technologies are, which is often correlated with public acceptance. This is the case for CCUS as a whole, but also for CCS and CCU technologies individually. For example, a focus group study conducted in Spain by Oltra et al. [27] reveals that opinions on CCUS technologies range from negative to neutral, predominantly due to perceived risk and lack of trust. Participants have a clear preference for renewables, and tend to reject CCUS technologies [27]. Similarly, Perdan et al. [25] finds a correlation between the level of awareness of CCU and support for the technology in the United Kingdom. Another interesting note discussed in two of the articles selected is that CCU and CCS terms are used interchangeably. This is found in a media discourse analysis conducted by Buure et al. [10] and Bruhn et al. [28]. The conflation of these technologies suggests a general lack of public awareness of CCUS technologies by the public.

However, when there is greater public awareness of climate change and CCUS technologies, CCUS, CCU, and CCS are portrayed in a positive light, thus increasing public acceptance. A study by De Best-Waldhober et al. [22] investigated this by conducting two surveys: an informed choice questionnaire and a traditional questionnaire in the Netherlands. The conclusion illustrates that the Dutch public is unaware of CCS. However, when informed, perception is mostly positive [22]. Similarly, Pinata et al. [29] finds that participants are generally unaware of CCS, but those who are aware perceived the social and environmental benefits of its implementation. Similar conclusions are drawn in the majority of the articles (e.g. [30][31][25][13][23][10]). This suggests that low awareness of CCUS appears to be global, but could be supplemented by informing the public on the importance of CCUS, CCU, and CCS.

2.1.3 Media Framing and Discourse Surrounding CCUS technologies

Few studies analyse media frames from an international perspective and compare public perception of CCS, CCU, and CCUS. Furthermore, only four articles conduct media analysis of CCUS technologies. However, existing media frame analysis on individual countries and technologies can provide an idea of how CCUS technologies are framed and how this differs per region.

The way in which media frames CCUS technologies generally indicates public acceptance of CCU and mixed viewpoints on CCUS and CCS. In a framing analysis of German-speaking media on CCU conducted by Fürst and Strunge [14], three main frames are found: the "climate protection" frame, the "CCU consumer product" frame, and the "economy-benefit" frame. The article concludes that CCU is viewed as positive by German media, which suggests that public acceptance of this technology is present in Germany. Contrarily, for CCUS, the discourse analysis conducted by Buure et al. [10] reveals that CCUS is framed as expensive and associated with regulatory issues. This suggests that the public views CCUS as a risk rather than a benefit.

Critical framing is also present for CCS. Using media content analysis and two main frames ("critical" and "enthusiastic"), Wædegaard et al. [15], finds that the critical frame is more pronounced in Danish media, and that it diminishes general support and funding for CCS. However, the framing of CCS in Europe appears to contrast the results in the United States. Feldpausch-Parker et al. [18] conducted a study on U.S. media framing of CCS, which finds that benefit framing is more common than risk framing. The study also finds that issues tend to be framed as political, legal, technical, and economic issues [18].

2.1.4 Overall Observations of Review and Implications for This Study

Views on CCUS, CCS, and CCU are relatively mixed, but mainly concern issues or benefits that are related to economic and environmental reasons (e.g. leakage risks, high costs). It is also clear that few studies take a media frame analysis approach to investigate the perception of CCUS technologies, and how media portrayal differs per region. Thus, this further highlights the importance of including an international comparison of CCUS, CCU, and CCS perception, and how the framing might vary between regions.

2.2 Theoretical Framework

Table 1: Risk and Benefit frames present in the SPEED framework. Table contents taken directly from Stephens et al. [32], page 12.

SPEED frame	Benefit	Risk
Technical	Engineering advancements, technical change and developments, interactions creating new opportunities	Needs or vulnerabilities, negative technical aspects of systems change
Economic	Strengthening the economy (e.g. creating jobs), saving money, creation of economic opportunity	Increased costs to different actors, higher economic uncertainty or risk
Political	Enhanced energy independence and national security, energy security, improved reputation of a region or state	Public frustration, difficult legal and regulatory processes from system change
Regulatory & Legal	Progress towards policy goals, effectiveness of legal framework to enhance system function	Difficult legal processes stalling system change
Environmental	Reduced GHG or carbon emissions, mitigation and adaptation of climate change, energy conservation, minimal air and water pollution, improved public and environmental health	Threat to environmental and public health, shifts risks to new environmental areas
Cultural	Community pride, positive behavioural change	Concerns of privacy, loss of control, inequality, perceived negative impacts on way of life

In this research, the methods used in sections **2.3** are applied through the lens of the Social-Political Evaluation of Energy Deployment (SPEED) framework, which is an interdisciplinary approach that can be used to systematically analyse factors, both risks and benefits, that influence the deployment and development of energy technologies (see Table 1) [32]. It was developed in 2008 by Stephens et al. [33] after noticing there was a research gap in energy technology diffusion. This research area typically focuses on the technical and economic aspects of energy technology implementation, overlooking socio-political factors (e.g. regulations, laws, public perception) [32][33]. However, these aspects are important, since negative public perception and poor regulatory structures can halt technology deployment entirely [33]. As such, SPEED was developed to include all of these factors.

The SPEED framework stipulates that the implementation of emerging technologies relies on six functions: technical, economic, political, regulatory & legal, environmental, and cultural [32][18]. The technical element refers to typical technical factors that could influence deployment of a technology (e.g. rapid engineering advancements) [32]. The economic element describes aspects that relate to finances, the current market, and the cost of the technology. The political element details the potential political gains (e.g. energy security or improved reputation) or downfalls of the deployment of the technology being analysed. The regulatory & legal element refers to existing regulatory structures that support or prevent the deployment of a technology. The environmental element describes the factors related to the health of the public and the physical environment. The last element, cultural, includes the social aspect of technology deployment (e.g. social acceptance, community engagement).

One of the main benefits of SPEED is that it provides a concrete framework that researchers can utilise to study the context in which technology deployments occur, linking the technical and policy side of energy transition issues [32]. This aids in holistically understanding the risks and benefits of deploying a particular technology, which could help provide a diverse range of perspectives [32]. Given that CCUS technologies are relatively nascent, using such a tool to analyse news media could determine how this technology is discussed by the public (e.g. from an environmental or political point of view) and thus uncover the implications on public perception.

2.3 Research Approach

This research analyses news media from the Nexis Uni data base in three different regions with a mixed-methods approach: quantitative content analysis and media frame analysis (see **Section 2.3.2** for the chosen regions). Content analysis is a research method that can be used to gain a deeper understanding of messages, which can be in various forms (e.g. media outputs, audio recordings, and images) [34]. A key feature of content analysis is its approach, which can be qualitative or quantitative. Qualitative approaches are more inductive, possibly involving the analysis of the relationship between the audience of a text and the text itself [34][35]. Quantitative approaches are more systematic and use an a priori design, as the data is typically analysed with pre-existing themes [34][35]. Such an analysis can uncover perceptions of what companies, people, and organisations are thinking about on a particular topic [35]. Media frame analysis is a qualitative form of content analysis. In Van Hulst [36], the core of framing analysis is described as the idea that a problem or solution can be understood in various ways ("frames"). Within a piece of text, there are multiple frames present that will influence the perception of a topic to the target audience [37]. Frames present in a text are selective, and thus not neutral [37]. Consequently, they can influence public opinion through highlighting one part of reality and communicating it to the chosen audience [36] [37].

The main purpose behind utilising two methods is to ensure a more complete picture of the data is created, which can be supported through the use of a quantitative and qualitative methodology [38]. Furthermore, using two methods can alleviate the weaknesses of the methods used, thus increasing scientific rigour [38]. Media in particular is chosen as a way to investigate perception of CCUS technologies due to the critical role it plays in the agenda-setting stage of public policy [39]. When analysing issues related to the energy transition, media output has a large influence on public discourse on a topic, and the stories put out by publications can determine how the public will interpret the issue being discussed [40]. Furthermore, for newer technologies like CCUS, media framing plays a key role in the success of the technology. Positive framing can lead to path dependency, thus increasing the chance for success [40]. However, if economic or safety risks, for example, are mainly highlighted, the technology could lose support from the public. Thus, choosing this text type as a medium for analysis can provide insights into how CCUS is framed in general across regions, and thus can potentially uncover how the public may feel about this technology.

2.3.1 Coding Procedure and Data Analysis

This research uses ATLAS TI for coding, an online tool with a qualitative coding interface in which PDFs of the articles can be uploaded and coded in a single environment. The selected texts are coded with an a-priori design through the lens of two main frames, "risk" and "benefit", for each of the six elements in the SPEED framework: technical, economic, political, regulatory & legal, environmental, and cultural (see Table 2 for the code book). For each article, quotes that contain themes related to one or more of the twelve sub-frames present are assigned codes. If one or more sub-frames are present in a quote, it is tagged with multiple codes to ensure all relevant frames are taken into account. Certain topics also may have the same code; for example, continued use of fossil fuels is an environmental risk but could also be described as an economic benefit. In these cases, the context of the article is taken into consideration to see which frame is most relevant. The texts are also coded if a specific technology is mentioned ("CCU", "CCS", and "CCUS") to determine if there is a distinction in framing. As the articles are analysed, other codes are added as relevant themes arise to ensure they are taken into account. Quotations are also manually selected while coding to support the observations. Once all of the articles are coded, the same coder will re-code a 10% sample of each region. It should be noted, however, that such a procedure in a typical study would be carried out by a team of researchers, known as "inter-coder reliability", to ensure the data is reliable, reduce error, and increase rigour [35]. However, since this project is an independent master's thesis, the assigning of codes relies on the judgment of one coder.

The resulting data consists of a list of quotations and corresponding codes for articles from each region analysed. The frequency of the six frames present in the SPEED framework are counted in all the articles to determine which frame is dominant in each region. Additionally, the prevalence of the risk and benefit frames is compared. The aim of this is to determine if CCUS technologies, across regions, are portrayed as a risk or benefit more often, and if references are framed as political, environmental, cultural, technical, economic, and/or regulatory & legal issues more frequently.

Table 2: Media frame analysis codebook. Based on the SPEED framework presented in Stephens et al. [32] and an existing codebook in Wilson et al. [41]

SPEED Frame	**Benefit**	**Risk**
Technical	The technology is reliable and/or efficient - advancements in the technology are present (e.g. less energy consumption than other CCUS, CCU, or CCS methods) - infrastructure exists or is in progress of being built (e.g. using existing saline aquifers or depleted oil fields)	The technology is not proven at scale or "mature" enough - infrastructure challenges present (e.g. not enough CO_2 storage capacity); technology does not work - technology is inefficient and/or unreliable (e.g. high capture rates unachievable)
Economic	The technology strengthens the economy (e.g. creating jobs, preserving existing jobs) - technology is described as " an investment opportunity", "business opportunity", and/or profitable (e.g. using CO_2 to make new products) - lower cost compared to other technologies - allows for the continued use of fossil fuels	The technology is costly - specifically coded as "increased cost to tax-payers" if this is mentioned in the article
Political	The technology increases competitiveness with other regions (e.g. puts them "ahead" in advancements) - improvement of reputation of the country/region mentioned in the article - higher energy security	Comparisons between regions and countries in a competitive manner (for example, one country being described as "ahead" of another country, thus painting this country in a bad light)
Regulatory & Legal	Progress towards policy goals made - efficient regulatory structure - government support is present (e.g. tax incentives) to encourage system change	Difficult permitting or legal processes present that affect deployment (e.g. obtaining storage sites) - lack of government support present to encourage system change (e.g. lack of tax credits)
Environmental	The technology reduces CO_2 or GHG emissions and mitigates climate change - explicitly coded as "decarbonises hard-to-abate sectors" when such sectors are mentioned - coded as benefit when referred to as "environmentally-friendly", "green", etc	The technology has negative environmental impacts (e.g. increased CO_2 emissions, habitat destruction) - technology impacts public health (e.g. drinking water quality, leakage) - allows for the continued use of fossil fuels
Cultural	Community pride in the discussed technology	Negative impacts on people's way of life (e.g. impact to property) - loss of control (e.g. use of eminent domain to take land for carbon storage)

2.3.2 Country and Data Collection

Data is collected on Nexis Uni, an academic database containing a wide range of resources, including but not limited to newspapers, business articles, and blogs. Three regions are chosen in which the same search terms and filters are applied: North America, Europe, and the Middle East. These locations are chosen due to the prevalence of CCUS technologies in each region. In all three regions, major CCUS projects have already been deployed, with the number of plants projected to increase by 2070 (see Figure 1). Thus, it is likely that media in these regions have existing publications on CCUS technologies, thus providing more data points for research. The time frame applied in this research is 2020 to 2025; the Nexis Uni database has a larger time frame present, but this is the period in which more newspapers discussing CCUS technologies are published. The specific search terms used are listed in Figure 2. These terms are chosen to ensure a wide range of text is available, while also making sure irrelevant articles are minimised. Furthermore, an additional geography filter is set to remove irrelevant articles from the batch.

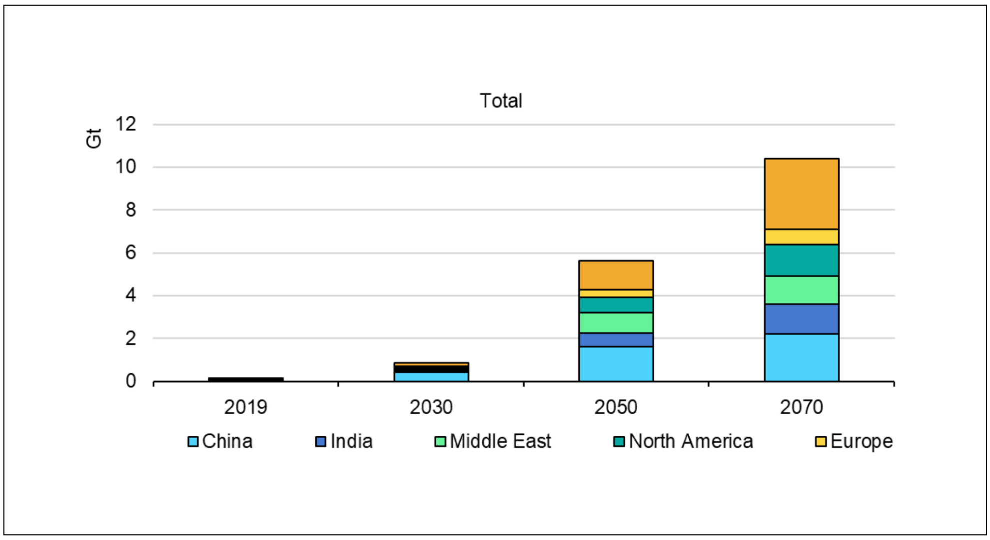

Figure 1: Captured CO_2 emissions by region in the Sustainable Development Scenario, 2019-2070. Taken directly from the IEA [5].

(CCUS or CCU or CCS) and (Carbon capture or Carbon utilization or Carbon storage)

Figure 2: Search terms used to select media articles in the Nexis Uni database

Newspapers are chosen as the text type for this research due to their key role as community resources, thus having an influence on public opinions [42]. An English language filter is also applied to ensure consistency is maintained across all regions. As a consequence, the native languages of the countries analysed is omitted, which could remove certain perspectives that would otherwise contribute to the results.

Table 3: Article batches per region after the search terms and filters in section **2.3.2** are applied

Region	Number of Articles
Middle East	542
Europe	2856
North America	3153

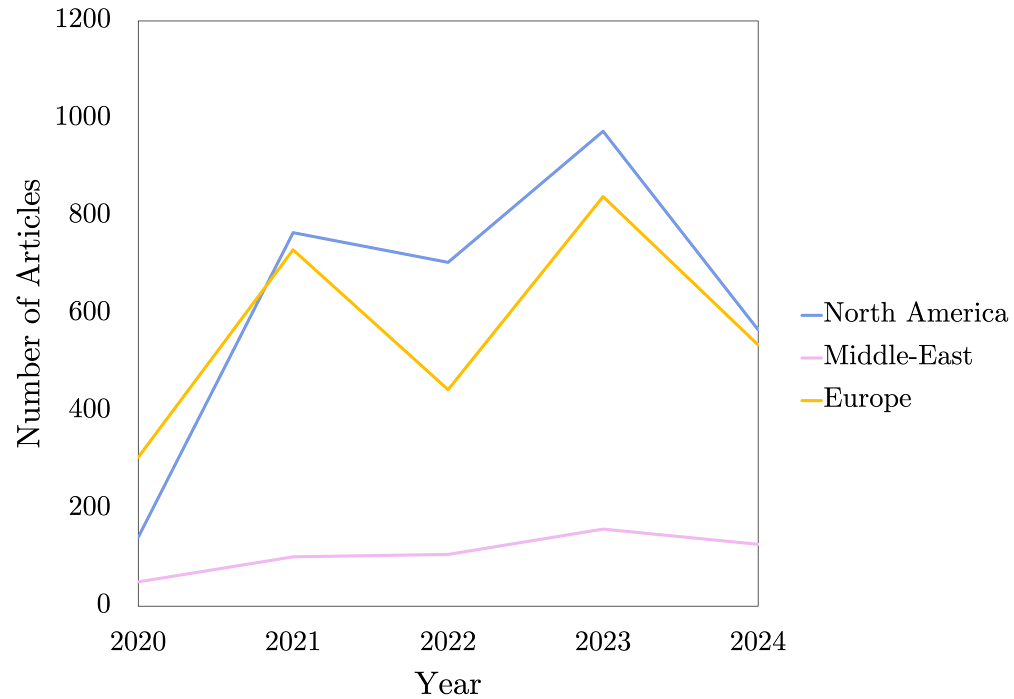

Figure 3: Number of articles per year for each region.

Applying the chosen filters and search terms results in a varying number of articles per region in total (see Table 3). The North America and Europe have the most articles present in the database, while the Middle East has a low number of articles present across the entire time span chosen. This is also reflected when looking at the number of publications per year for each region (see Figure 3).

2.3.3 Sampling Process

For each region, all articles are downloaded in batches of 500 in PDF format, which is the maximum limit of articles that can be downloaded in one batch on Nexis Uni. The PDF's are then subsequently uploaded to Atlas TI for analysis.

The appropriate sample size is a topic of debate amongst qualitative researchers, as there tends to be criticism towards such research for the lack of justification of sample sizes [43]. In general, the sample size is largely dependent on the scope of the study and the topic being studied [43]. It should also be large enough to ensure it is representative of the population [43]. Thus, for this research, a sample size of 100 articles per region is chosen. The scope of the study is relatively broad, meaning a higher number of articles must be sampled from the population of each region. However, due to time constraints, 100 per region is the maximum amount that can be analysed. To ensure articles are not selectively chosen for analysis, every nth article is manually selected for each region, as done in Upham and Ibrahimović [44]. This is to ensure there is equal representation of each region despite more articles being published in Europe and North America. The sampling interval for each region is calculated by dividing the total number of articles by 100. The starting point is the first nth article in each region. For example, in North America, every 30th article is selected, starting from article number 30.

Irrelevant articles are manually skipped, which includes those that are unrelated to the topic, if CCUS technologies are mentioned briefly, or if it is identical to the previous article. If many articles are skipped by the end of the analysis, articles will also be randomly selected to ensure relevant articles are coded and that the 100 article quota per region is met.

3 Results & Discussion

3.1 Dominant Framing of CCUS Technologies Across the Studied Regions

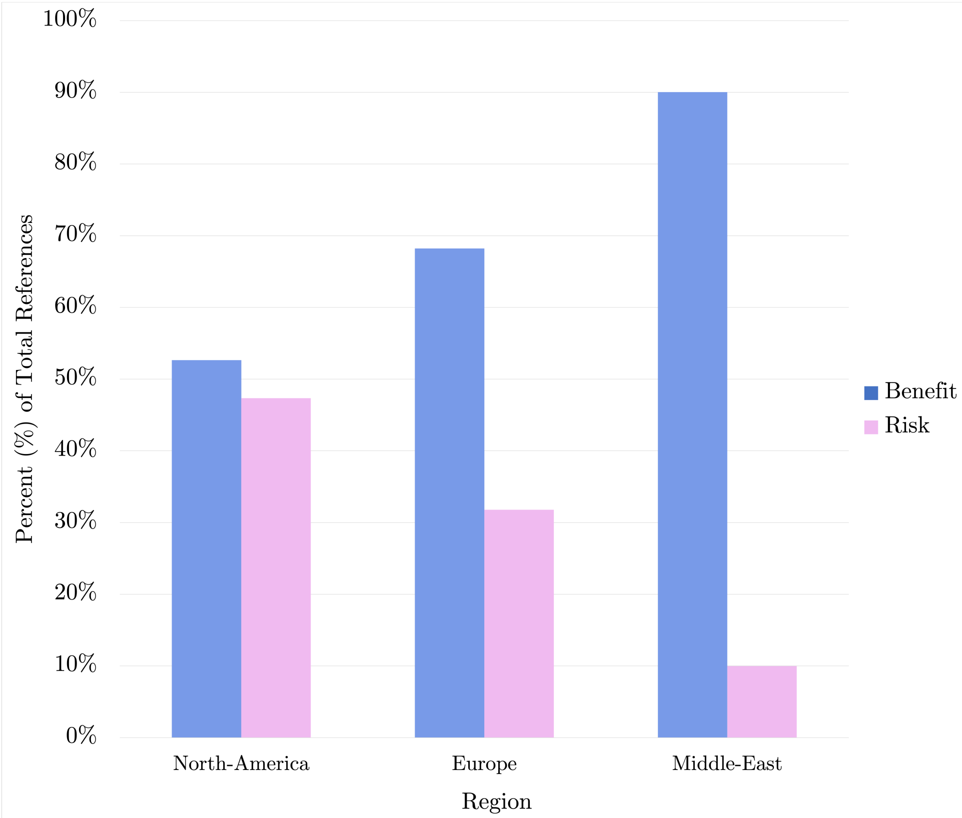

Figure 4: Percent (%) of references associated with risk and benefit frames.

Figure 4 illustrates a comparison between overall risk and benefit framing per region for CCUS technologies. Across all regions, it is clear that CCUS, CCU, and CCS are mainly framed as beneficial rather than a risk. Additionally, articles are typically one-sided amongst all regions, usually containing benefit or risk framing. In this sense, risk and benefit framing rarely co-occurred. When comparing regions through the lens of the SPEED framework, the three regions also have similar framing of CCUS, which will be discussed in more detail in sections **3.1.1**, **3.1.2**, and **3.1.3**. For a comparison of SPEED frames between regions as well as raw data, please see **A1-A3** in the appendix. The complete list of codes and corresponding references is also attached in the supporting document (**S2**). Additionally, more supporting quotations relating to SPEED frames in each region can be found in **A5-A7** of the appendix.

3.1.1 North America

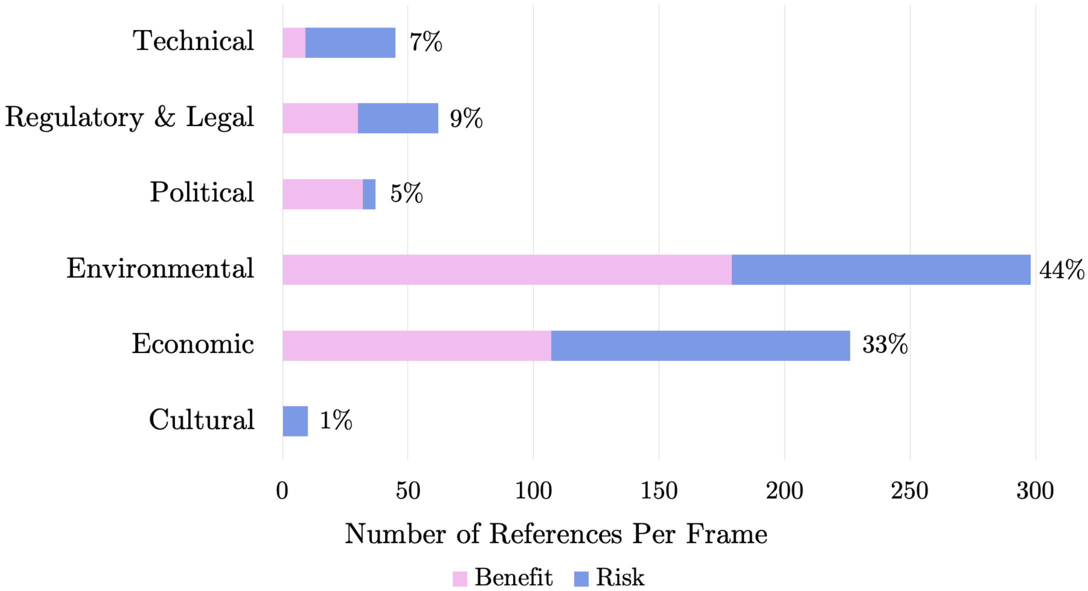

Figure 5: Distribution of risk and benefit frames amongst the SPEED frames in North America.

In North-America, CCUS technologies are mainly discussed as environmental and economic issues (See Figure 5). Technical, political, and cultural frames are present, but comprised of less than 10% per frame of the total references for the region. Furthermore, Canada is highly represented in the sample mix compared to other nations present in North America, comprising of 57% of the articles. As such, most of the media framing is from a Canadian perspective rather than the region.

When looking at the distribution of risk and benefit frames, it is evident that CCUS technologies are framed as environmental benefits more commonly than a risk. The reasoning behind this generally followed the narrative that CCUS, CCU, and CCS could reduce GHG emissions. For example, one article described capturing and storing carbon as the "ticket to drive down emissions" that will pave the pathway to net-zero (Heesu Lee, Bloomberg and Financial Post, 2021)(for full references in all regions, see **A4** in the appendix). These technologies are also viewed as essential to abate certain industries where emissions are unavoidable (e.g. cement), describing CCUS technologies as "the only way to reduce their emissions" (Laura Legere, Pittsburgh Post-Gazette, 2020). The environmental risk frame is also prevalent, despite it being mentioned less frequently. Articles tended to depict CCUS technologies as a distraction from renewable energy, allowing for the continued use of fossil fuels. This reasoning is often linked to enhanced oil recovery (EOR) being the main use of CO_2, which involves using CO_2 to pump extra oil from reservoirs.

From an economic perspective, CCUS technologies are depicted as a risk more often than a benefit by a small margin. The arguments for North America focused on the high costs of CCUS technologies, explaining that it is too expensive to invest in. Another common argument is that a substantial amount of public dollars are being spent on the technology, sometimes being described as a "tax-payer handout to the oil industry", highlighting that North American media frames CCUS technologies as a dual economic and environmental risk (John Cox, The Bakersfield Californian, 2023). It should be noted, however, that economic benefits are frequently mentioned in the articles, and often co-occurred with environmental benefit framing. Many articles focused on the importance of oil, specifically in the context of the Canadian oil sands in Alberta, in which EOR came up frequently as a way to continue oil production with captured CO_2. In this sense, CCUS, CCS, and CCU are seen as a way to preserve the oil industry while meeting net zero targets, creating new jobs, and making “low-cost, low -risk, and low-carbon” oil (Chris Varcoe, Sherwood Park News, 2021).

While less common, the regulatory & legal frame also is a point of discussion amongst the North American articles, mainly from the point of view of Canada. This frame is referenced in articles that discussed government initiatives, mainly tax credits, to boost CCUS technologies. Often times, these articles reflected that oil companies are not satisfied with the measures, and felt that the U.S. government provided more support to oil industries. Interestingly, the political risk frame came up in such references. There is a fear present that Canada risks to ”lose out on the race” compared to the US if tax credits are not improved for CCUS technologies, limiting the transition to a sustainable future (Michele Jarvie, The Calgary Herald, 2023).

3.1.2 Europe

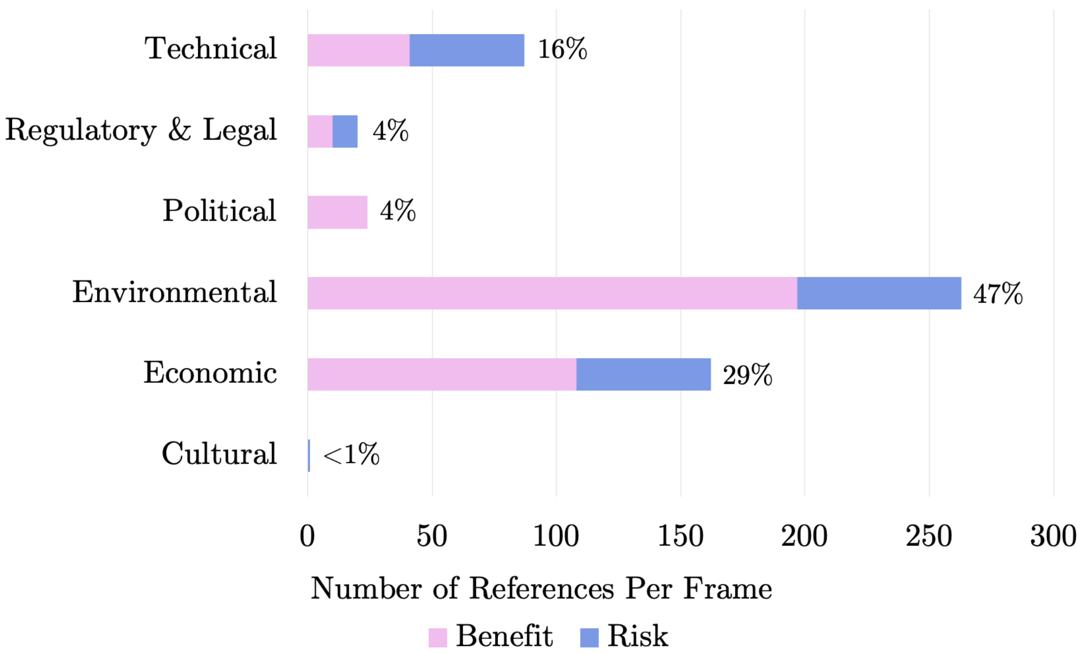

Figure 6: Distribution of risk and benefit frames amongst the SPEED frames in Europe.

In Europe, CCUS technologies are framed mainly as environmental and economic issues by the media (see Figure 6). Technical framing is also present throughout the articles, but the cultural, regulatory & legal, and cultural frames are far less prevalent. Furthermore, similarly to North-America, there is unequal representation of countries in the sample. The majority of the articles are sourced from the United Kingdom (UK), comprising of 76% of the sample. Thus, the media framing largely represents the UK perspective rather than the entirety of Europe.

From an environmental perspective, European articles frame CCUS technologies as a benefit. The reasoning behind this is similar to North America, in that CCUS is framed as a way to mitigate climate change and reduce CO_2 emissions, often being described as a ”critical emissions-reduction technology” (Mark Hatfield, Global LNG Monitor Today, 2022). Furthermore, similarly to North America, CCUS is framed as a way to abate process emissions and ensure climate targets are achieved (Daniel Wetzel, Die Welt am Sonntag, 2022). When analysing the risk frame in particular, the reasoning mirrors opinions in North American articles. There is a sentiment present that CCUS technologies are an excuse for fossil fuel industries to emit more CO_2. Some articles describe CCUS technologies as a fantasy and a ”step-backwards” towards future climate goals (Caroline Dougherty, Irish independent, 2023). In this sense, there appears to be a fear that CCUS technologies could be used for the wrong reasons and delay progress towards limiting CO_2 emissions.

The economic perspective is the second most common framing in European articles, with a higher number of articles framing CCUS technologies as economically beneficial. Most articles focus on how CCUS technologies can benefit the UK specifically, often times mentioning the Scottish cluster as an example. In many articles, CCUS technologies are seen as a way to boost the economy and lower the cost of reaching net-zero. Alongside this, articles frame CCUS technologies as a source of jobs for local communities, which have the potential to "support an average of more than 15,000 jobs" between 2022 and 2050 in Scotland (Allister Thomas, Aberdeen Evening Express, 2022).

CCUS is also discussed frequently as a technical issue by European articles, predominantly being framed as a risk. The most common narrative behind the risk framing is the age of the technology, many articles describing it as unproven at scale and compared to "building castles in air" (Global Capital Euroweek, 2022). Although less frequent, the technical benefit frame is also mentioned in articles, often from the UK perspective. In such references, the "transferability of oil and gas workers skills" is highlighted as a way to use existing knowledge from previous sectors while building a net-zero workforce for the offshore energy industry (Mike Tholen, Scotsman newspaper, 2021).

There is also a high level of pride present in the UK energy industry present in the European articles. In such newspapers, Scotland in particular is framed as a world leader of CCUS technologies, and that CCUS is a way to "revitalise the birthplace" of the first industrial revolution (Mark Williamson, The Herald, 2021). In this sense, there is a political benefit frame that appeared in the European sample, albeit at low frequency.

3.1.3 Middle East

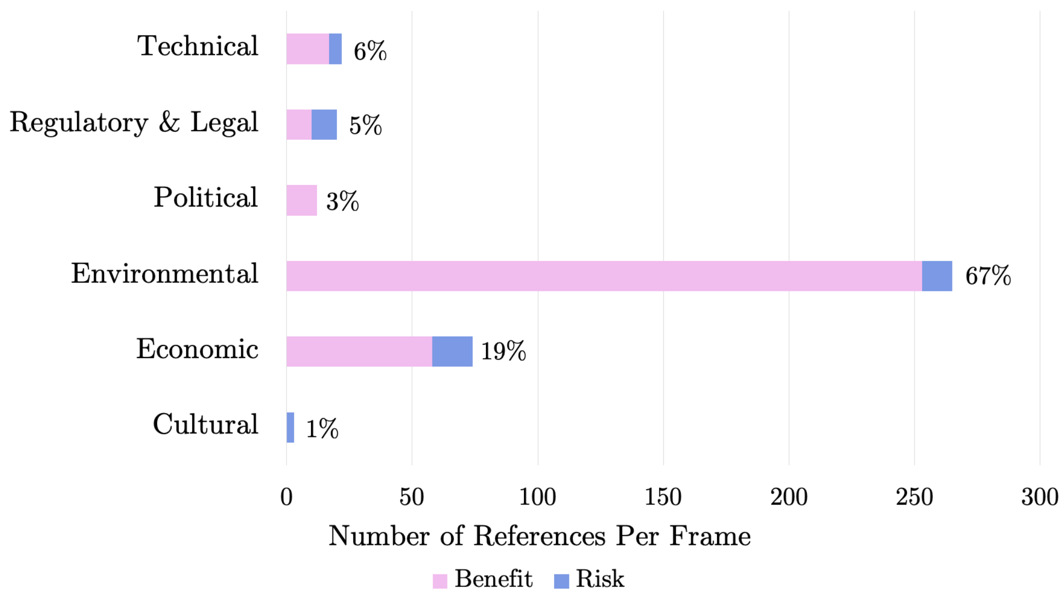

Figure 7: Distribution of risk and benefit frames amongst the SPEED frames in the Middle East.

It should be noted that only 88 articles are coded for the Middle East, as less relevant articles are present in the sample. This aside, the Middle East has a unique distribution of frames compared to Europe and North America, with 90% all references being framed as a benefit rather than a risk (see Figure 4). While CCUS technologies are also framed mainly as environmental and economic issues, the environmental frame represented 67% of the references from the sample (see Figure 7). Other frames are not as frequent, comprising of less than 7% of the total references per frame.

Similarly to North America and Europe, from an environmental perspective, CCUS, CCU, and CCS are mainly viewed as a way to prevent CO_2 emissions from reaching the atmosphere. In this sense, CCUS technologies are framed as key tools for upcoming net-zero emissions targets (Oman Daily Observer, 2024). There are few references that frame CCUS technologies as an environmental risk (see Figure 7). However, the references that are labelled as a risk appear to discuss other countries use of CCUS technologies rather than countries within the Middle East. This is the case for an article published in The Peninsula which discussed Australia's funding of CCS, mentioning that CCS will "extend the life of dirty fossil fuels" (The Peninsula, 2021). Similar negative framing is present in a Gulf Times article published in 2023, which discusses that companies in the U.S. have had slow progress due to safety concerns of CCS (Gulf Times, 2023).

CCUS technologies are also discussed as an economic issue in Middle Eastern articles, being framed mainly as beneficial. Similarly to North America, another common topic of discussion is the use of CCUS technologies to preserve the petrochemical and oil refining industries while also meeting climate goals. Certain articles specifically described the technologies as a "significant step towards sustainable oil and gas production" that align with net-zero emission goals in 2050 (Muscat Daily, 2023). The concept of EOR is discussed as a way to use CO_2 in this regard, often times being framed as "at the forefront" of the Middle East CCUS approach (Middle East Oil & Gas Monitor, 2020). In this sense, CCUS technologies are seen as an essential component to the future of energy production.

Also related to the economic benefit frame, another theme present is the concept of a circular carbon economy, which has a focus on ensuring captured CO_2 is utilised. In Middle Eastern articles, carbon is viewed as an "opportunity" with the implementation of a circular carbon economy, rather than an "enemy", as stated by Saudi Arabia's Energy Minister Prince Abdulaziz bin Salman bin Abdulaziz (Sebastian Castelier, Haaretz, 2021). This concept is further detailed in other articles as well, being described as "a resource with real economic value, rather than a pollutant" in the Saudi Gazette (Saudi Gazette, 2024). A similar sentiment is also present in two articles from the Saudi Gazette in 2020 and 2021. The presence of this theme is unique to the Middle East in that there is little discussion of the utilisation of CO_2 aside from EOR in the North American and European samples.

3.2 Use of Terms CCU, CCS, and CCUS

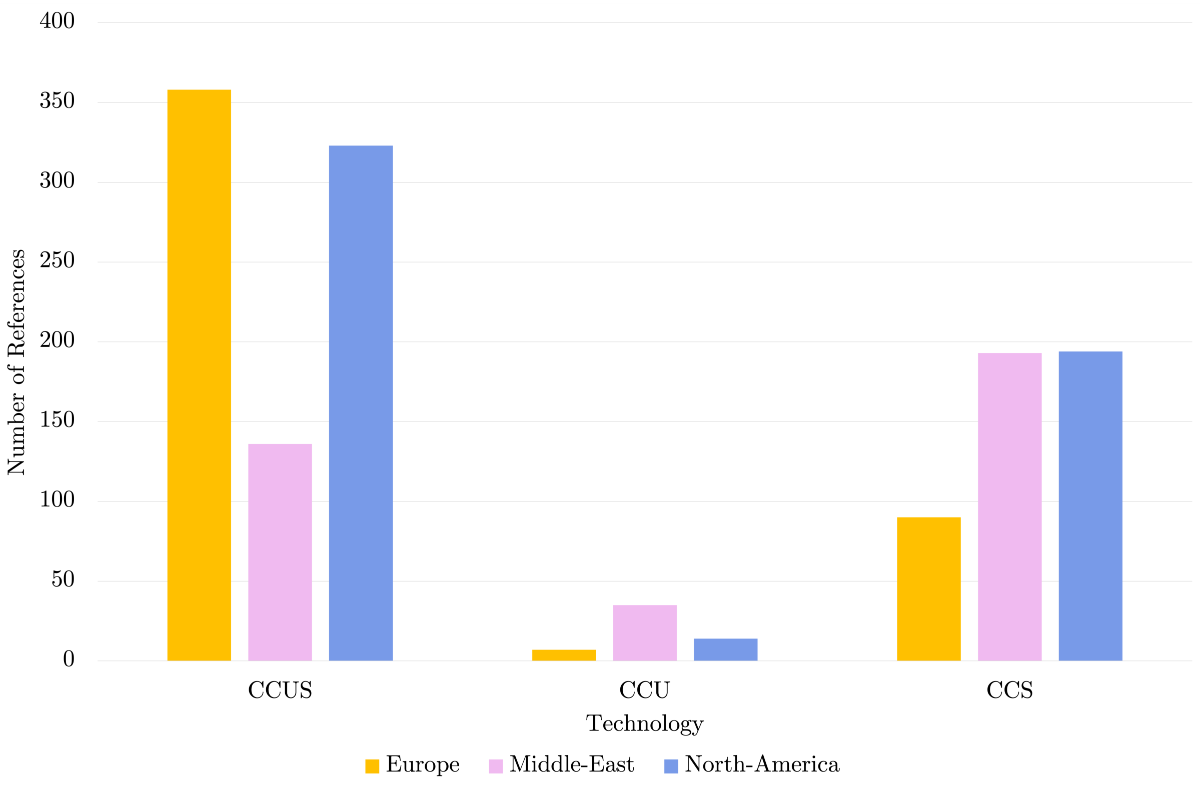

Figure 8: Number of references being classified as CCUS, CCU, or CCS.

In all three regions, CCUS and CCS are referenced more frequently in articles compared to CCU, which comprised of less than 50 references for each region (see Figure 8). As a consequence, it is difficult to draw meaningful comparisons in SPEED frames between each technology. Instead, the difference in frequency of CCUS, CCS, and CCU between the three regions is discussed (see **A8** in the Appendix for visual representation of the co-occurrence data of SPEED frames and CCUS technologies).

In Europe and North America, CCUS is mentioned more frequently compared to CCS and CCU, possibly because it is an umbrella term that encompasses the storage and utilisation of CO_2. Notably, in the Middle East, CCU is mentioned more frequently compared to the other two regions. This is also noticeable during coding, as articles from the Middle East sample have a higher focus on the utilisation of CO_2 and consistently referred to it as an economic opportunity rather than waste.

Furthermore, articles in the Middle East tend to make a clearer distinction between CCUS, CCS, and CCU compared to North America and Europe. In some North American articles in particular, CCS and CCUS are also used interchangeably. An example of this can be found in an article published by the North American Oil & Gas Monitor in 2022, in which it is stated that CCS is also known as "CCUS" (North American Oil & Gas Monitor, 2022). A similar conflation is also present in an article in the Pantagraph newspaper, in which carbon capture is described as the "injection of CO_2 into wells in geological formations", also being referred to as CCUS (Andrew Adams, Pantagraph, 2023). In this reference, the process of capturing carbon is also conflated with carbon storage, further highlighting the unclear distinction between different CCUS technologies. While these mistakes are not made in the European sample, it is evident from the high number of references that CCUS is a general term used to describe CCS and

CCU, despite individual technologies typically being discussed in articles. For example, articles that utilised the term "CCUS" often times would only discuss carbon capture, carbon storage, and/or carbon utilisation.

3.3 Discussion

The results of this research indicate that there are two frames amongst all regions that represent the majority of the media narrative on CCUS, CCS, and CCU: environmental and economic framing. Regulatory & legal framing, as well as technical framing, are also relatively prevalent, but at a lower frequency compared to environmental and economic framing. Of these two frames, it is evident that the benefits tended to dominate over the risks. However, particularly with North America and Europe, there is a significant portion of risk framing still present. Thus, despite the higher frequency of benefit framing, public perception appears to be relatively mixed. These results partially agree with literature. When reflecting on the general framing, Fürst and Strunge [14] also finds environmental and economic frames associated with CCU. Similar results are found for CCS in Feldpausch-Parker et al. [18], in which economic and technical framing is also highly referenced with CCS. However, the results appear to contrast literature when comparing if CCUS technologies are framed beneficial versus as a risk. This is the case for Buure et al. [10], which finds that CCUS is framed as expensive and associated with regulatory issues. While similar framing is highly referenced in North America and Europe, this is not the majority. However, Buure et al. only focused on Finland, while this research focused on whole regions, which could also explain why the results varied.

When analysing the differences in framing between CCUS, CCU, and CCS, the results are not clear. This is perhaps attributed to the unclear referencing of CCUS technologies present in media, particularly for North American and European articles. In these regions, it is not defined properly at times which technology is being discussed. While media outlets frequently use the term CCUS throughout articles, often times a singular technology within CCUS is discussed (e.g. carbon storage, carbon capture, carbon utilisation). This result directly agrees with previous literature, both framing analysis and surveys, on public perception of CCUS technologies. In the media discourse analysis conducted by Buure et al. [10], it is found that the terms CCU and CCS are often interchanged in articles, highlighting the media's unfamiliarity with the subject. The same results are also found in a study conducted by Bruhn et al., [28], which finds that these terms are conflated in different political contexts, mentioning the U.S. department of Energy as an example, which lists CCU as a subset of CCS. Thus, this research, alongside existing literature, suggests that there is a level of unawareness of what CCUS is and how to describe the technologies that fall under this term (CCS, CCU). This could also partially explain the results found in the surveys discussed in the literature review, which often mentioned that the public is unaware of CCUS, CCU, and CCS [27][25].

Such conflation of terminology could have negative implications for public acceptance and hinder technology development. Interchanging terminology for separate technologies can transfer the attitude of the intended technology to the discussed technologies, which could delay the deployment of a potentially beneficial technology [28]. The media's low awareness could also foster a lack of understanding to its consumers, the general public. As a consequence, this could create more distrust, which can potentially change public attitude towards a technology and thus hinder public acceptance [45].

Another notable point of discussion is the large difference in benefit frames present in the Middle East compared to the other studied regions. This difference is most prominent when analysing environmental and economic frames, in which few negative references are present. This result is perhaps attributed to control of the press in the Middle East. In many countries in the region, the press is highly controlled by the government. This can been seen by looking at the press freedom index score, which compares the freedom media and journalists have in 180 countries with a score from zero to 100, zero representing the worst score and 100 representing the best score. Nearly all countries in the Middle East (e.g. Yemen, Oman, Jordan) score below 50 from the years 2020 to 2025 [46]. Thus, it is reasonable to conclude that the countries governments might have controlled the narrative in the articles analysed, possibly attributing to the high fraction of benefit framing compared to the other regions.

An additional point that is less prevalent in the reviewed literature is the heavy focus on EOR alongside CCUS, CCU, and CCS in discussions. It is evident from the sampled articles that there is a focus on continued oil production in North America and the Middle East. Throughout the time span of 2020-2025, there is a clear emphasis on CCUS technologies being used as a way to preserve fossil fuel industries while meeting climate targets through the creation of cleaner oil. While this is not discussed in the studied papers, it is evident from other sources that EOR is becoming increasingly popular, as it can improve oil recovery by 10%-25% while also helping countries reach carbon neutrality targets [47]. It also appears favourable financially-speaking, as CCUS projects integrated with EOR could lower the cost of production from increased oil revenue [48]. This could explain why the media discussed CCUS in this context frequently, and why environmental risk framing refers to CCUS technologies as an excuse to emit fossil fuels.

3.4 Limitations

A key limitation to the results is related to the unclear definition between CCUS, CCU, and CCS present in the articles. Since articles are coded with the specific terms utilised rather than how they are described in the article, the actual terminology discussed (e.g. CCS) is not included in the frequency analysis and the subsequent media framing analysis. Thus, the results misrepresent what is stated in the articles at times. This could also explain why it is difficult to find differences in framing between CCUS, CCU, and CCS.

An additional limitation to the results in this research is the database used to obtain the articles, Nexis Uni. The database continuously removes and adds new articles, thus leading to difficulties in reproducing this research. Furthermore, the articles within the database tend to focus on one country per region, rather than a wide range. This is mainly the case for Europe and North America, and less so for the Middle East. In North America, 57% of the articles originate from Canada; for Europe, 76% of the articles originate from the UK. As a result, there is not a broad picture painted of CCUS technologies in each region, which potentially removed perspectives from other nations. For Europe in particular, this is perhaps due to the application of the English language filter.

The methodology itself also results in limitations. The allocation of specific frames to each quote relies solely on the judgement of the coder, which naturally leads to subjectivity and thus potentially affects the validity of the results. As such, it is possible that certain frames are missed within articles, or misjudged. In typical studies, this could be alleviated via the use of multiple coders. However, since this project is an independent masters thesis, this is not possible.

3.5 Future Research

For future research, a separate analysis should be conducted on each technology individually: CCU and CCS. This could demonstrate a better distinction between technologies to see if there is a difference in framing between regions. This might also provide a clear answer to sub-question C of the research question, which is not completed in this research.

Furthermore, it would be interesting to carry out similar research with different methodology that focuses specifically on the actors involved in the media. In this research, there is no analysis conducted on the different actors involved in the studied articles, and how power imbalances could affect the framing of a CCUS technologies. Thus, it might be of interest to conduct a critical discourse analysis to examine power structures in the text and how this shapes the public opinion.

On a more technical note, a different database could be used that does not refresh the data continuously to ensure reproducibility.

4 Conclusion

This research aims to uncover how the media frames CCUS, CCS, CCU in the Middle East, Europe, and North America between 2020 and 2025. Additional objectives are to determine the most common frame amongst all regions, if this differs between regions, and if there is a difference in framing between CCUS, CCU, and CCS.

Results indicate that environmental and economic framing of CCUS, CCU, and CCS are the most common across all three regions. For North America and Europe in particular, Regulatory & legal and technical framing is also prevalent. Other frames (i.e. cultural, political) are not common, comprising of less than 6% of total references for all three regions. Differences between regions mainly arise when looking at the frequency of risk and benefit framing. While benefit framing is the majority across all regions, risk framing is also significant, comprising of 47% and 32% of the references in North America and Europe respectively. Thus, for these regions in particular, it can be concluded that public perception appears to be mixed. Results for Middle Eastern articles, however, directly contrast those of North America and Europe. 90% of all the references frame CCUS, CCU, and CCS as benefits, mainly from an environmental and economic perspective. Differences in framing between CCUS, CCU, and CCS are difficult to discern, perhaps because terminology used in the articles is often undefined or unclear. However, when looking specifically at the frequency of the terms, it is clear that CCUS and CCS are referenced more in media across all three regions compared to CCU, which comprises of less than 50 references for all three regions. For the Middle East in particular, it should be noted that CCU references are more common compared to Europe and North America, and there is also clearer definition of CCUS, CCS, and CCU present.

5 Recommendation for the New Energy Coalition

The results of this research complement existing research on public acceptance and perception conducted by the ConcenCUS consortium, particularly Miu et al. [49] and Nielson et al. [50]. While the methodology used in Miu et al. [49] differs from methods used in this work (narrative analysis versus media framing analysis), an interesting comparison can still be drawn. It is evident that the framing and narratives of CCU(S) are not clear-cut, and depends on the country or region studied. In this sense, both this research and Miu et al. [49] highlight the complexity of public opinion, which adds a challenge in integrating such results into actionable tasks in an extension of the ConcenCUS project or future CCU(S) projects at the New Energy Coalition.

In this brief advice, this will be elaborated on, with the purpose of highlighting the importance of having a higher priority on the non-technical aspects in projects. The relevance of CCU(S) technologies as a whole will also be discussed, mainly from an environmental point of view.

5.1 The Relevance of CCU(S) to the New Energy Coalition

The definition of CCU(S) is often unclear and thus widely debated. In this research, the definition of CCU(S) technologies is derived from the International Energy Agency (IEA), which describes CCU(S) as the capture of CO_2 from a point source, along side the utilisation and/or storage of the captured carbon [6]. In this sense, CCU(S) can be considered an umbrella term for two technologies: CCS and CCU.

CCU(S) is currently a focal point at the New Energy Coalition, included in the "Sustainable Carbon" theme. Given the importance of CCU(S), this technology remains relevant to the New Energy Coalition and should continue to be included in this theme.

From an environmental standpoint, there are strong arguments present for increased deployment of CCU(S). Research clearly illustrates that there is high urgency to dually transition to green energy while also remove CO_2 emissions. According to a report conducted by the IEA in 2020, CCU(S) is included as one of the few viable ways to remove process emissions from hard-to-abate sectors s (e.g. cement, magnesium) [5]. This is further supported by the projected number of captured emissions across the world (as illustrated in Figure 1 on page 11), which will significantly increase from 2030 to 2070 in all major regions, including Europe. Specifically for CO_2 utilisation, CO_2 Value Europe predicts that up to 21% of carbon dioxide reduction by 2050 will come from CCU, with the captured carbon being used to create circular fuels (e.g. aviation fuels) and chemicals [51].

The aspect of carbon storage in CCU(S) technologies could be argued as less relevant to the New Energy Coalition, especially under the Sustainable Carbon theme. This study further supports such an argument, as results illustrate that two of the three studied regions (North America and the Middle East) view CCU(S) as a way to continue oil production. In such cases, it could be argued that the sustainable and circular aspect of CCU(S) is diminished. However, it is important to recognise that certain applications of CCU, like EOR, could skew public perception of the group of technologies. As previously stated in this research, conflating different technologies can transfer attitudes from one application (as with EOR) to other discussed technologies [28]. Such a conflation could potentially hinder the adoption of promising innovations like CCU, for example. Thus, while aspects of CCU(S) technologies may conflict with the Sustainable Carbon theme, the technology as a whole is highly relevant to the New Energy Coalition.

With this in mind, the ConcenCUS project has achieved remarkable technical progress, and thus deserves continued attention under the Sustainable Carbon theme. However, societal research - including this study - highlight challenges surrounding public perception and acceptance of CCU(S) technology. Such challenges, which are detailed below, must be taken into account for future CCU(S) projects at the New Energy Coalition, and for energy transition technologies more broadly.

5.2 The Importance of Public Perception in Energy Projects

Energy transition efforts typically focus on technical and economic factors. Thus, it is recommended that the New Energy Coalition places a higher focus on social acceptance and public perception in project design alongside the technical aspects, especially in a future continuation of the ConcenCUS project. This advice applies to energy transition technologies more broadly and is informed by both this research as well as the findings of the ConcenCUS consortium.

The main rational behind this advice is inclusion and ensuring that the energy transition includes society as well. In the energy transition, the social side is often overlooked. This is further highlighted in a paper by Maddaloni and Sabini [52], which examines the position of local communities in construction projects and how they are included in project management. While it is clear that inclusion of local communities is important in projects, there is a lack of focus on understanding why community involvement is important [52]. There is also little understanding as to why there is low community involvement in project decision-making [52]. As a consequence, communities often feel like a low priority in project decision making. Results from the ConcenCUS project also highlight such concerns, as communities from nearby pilot plants stated that they would have preferred to have been informed early-on and wanted a greater say in the engagement activities. Thus, solving such concerns would be a key recommendation for future projects at the New Energy Coalition.

Inclusion of communities, as well as cultural and societal factors, play a crucial role in shaping the energy transitions trajectory, and are major contributors to the success or downfall of projects [53][12]. Thus, communities points of view on projects are highly important to the success of a project. Including such aspects could not only improve the outcome of the project, but also directly aligns with the New Energy Coalitions strategic plan, specifically the support and participation focus. Of course, this has already been done for the ConcenCUS project. For other projects, similar studies could also be conducted to ensure narratives surrounding energy transition technologies are fully understood. This has the dual benefit of ensuring people are included in the energy transition, while also meeting company goals.

5.3 Advice on Communication Surrounding CCU(S) Projects

In this research, media framing of CCU(S), CCU, and CCS technologies is investigated with the aim of uncovering public perception of the technologies in each studied region (North America, the Middle East, Europe). While other methods are available to investigate public perception (e.g. surveys, interviews), media analysis in particular is chosen due to the critical role it plays in the agenda setting stage of public policy [39]. Media output can have a high influence on public discourse on a topic, especially for issues related to the energy transition. As already stated in this thesis, the way in which media frames issues (e.g. "leakage risk", "economic benefit") can determine how the public will interpret the issue being discussed. Article frames can be contradictory, and depend on the audience of the media, their values, and the level of scientific knowledge. Such an idea highlights the complexity of public's, and thus poses additional questions on how to properly communicate risks and benefits of CCU(S) technologies to society.

When discussing communication strategies, there is frequent discourse surrounding how to communicate energy transition technologies to the public, and if risks should be included in the conversation at all. Based upon the framing analysis conducted in this research as well as other literature, it is evident that communicating both risks and benefits of CCU(S) would be an appropriate approach to communications. This opinion is partially based on an interesting theme that arose during coding.

Downfalls of One-Sided Communication

While there were references present that had dual risk and benefit framing, often times articles focused on the risks or the benefits of CCUS, CCU, and CCS, rather than communicating a balanced perspective. In this sense, CCU(S) was generally framed as "good" or "bad" by the media in all three regions. This could be explained by the sensationalism bias, in which information is exaggerated or omitted to increase readership [54]. In the case of CCU(S) perception, one-sided representation of information could have implications to public acceptance of the technology. Exposure to one aspect of the technology can continue to foster misinformed perspectives to the public consuming the media, which could create either "pro-CCU(S)" or "anti-CCU(S)" mindsets, with little room in-between for balanced opinions. Additionally, actively communicating the benefits and setting aside risks of a technology could foster distrust amongst the community involved. Trust plays a key role in acceptance; if the public lacks knowledge on a subject, such as CC(U)S, communicating on part of a wider story will only foster more distrust between the project and the community involved [27][24]. This could hinder the success of a project. [10][12].

Benefits of Proactive Communication

Proactive and early engagement of public stakeholders addresses these concerns, and could bring a variety of benefits to CCU(S) and other energy transition projects. One key benefit is the prevention of misinformation. By proactively communicating both benefits and risks, the possibility of misinformation spreading could be lowered, and could mitigate any fear present surrounding the technology [55]. While this does not necessarily increase the effectiveness of the communication, it has the potential to build a trusting relationship between the project and the public [55]. Furthermore, the proactive communication of risks and benefits of CCU(S) can prevent extreme attitudes from forming, which further contributes to dampening the spread of misinformation [56]. This could potentially increase public acceptance of the project, especially if done in early stages while technical considerations are being discussed. Such an approach could also provide a realistic picture of CCU(S) to the public. If the benefits of a technology are inflated, expectations are raised; if something does not go as planned, this could contribute to disappointment and lead to controversies, which could be detrimental to the technology being discussed [57]. Thus, by communicating beforehand the benefits and risks of implementation, expectations can be managed if issues were to arise.

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Appendix

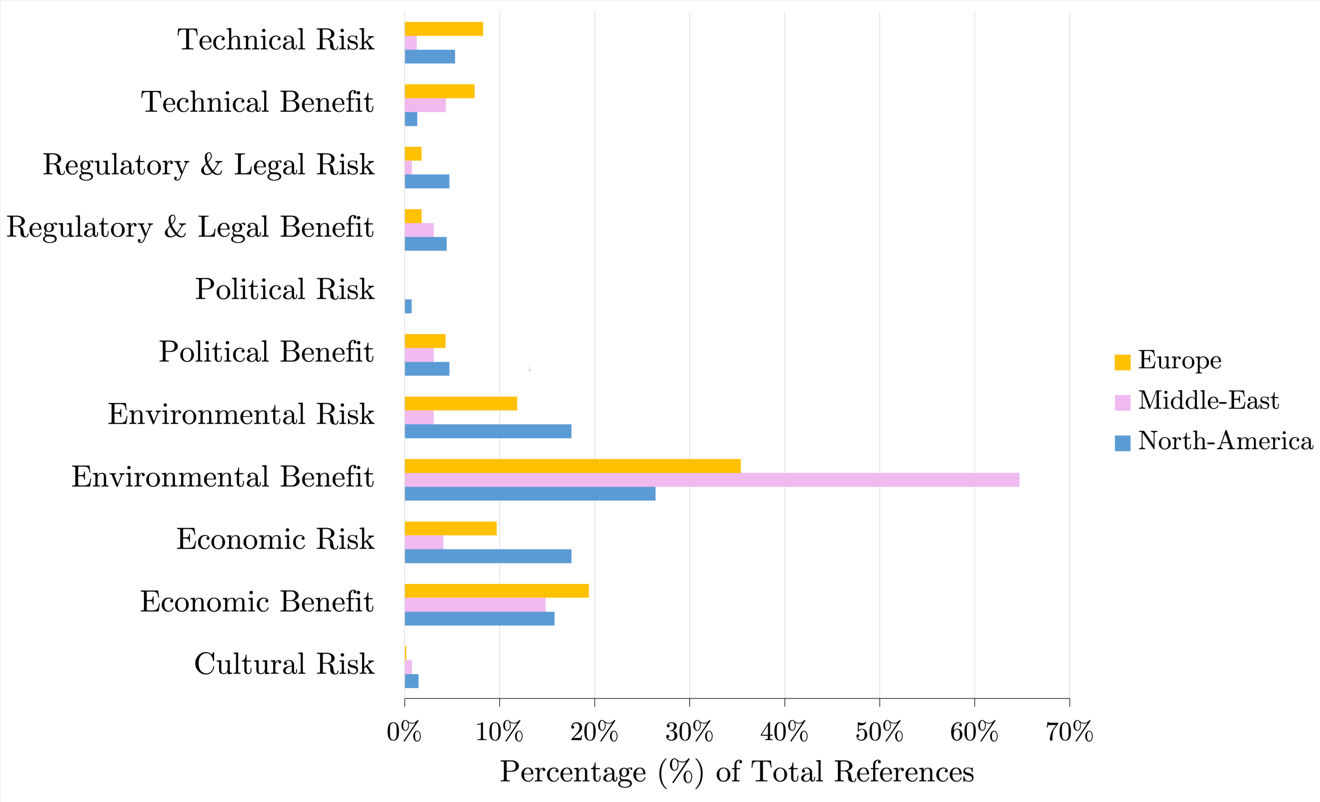
A1: Table with the number of references corresponding to each frame per region

SPEED Frame	North America	Europe	Middle East
Cultural Benefit	0	0	0
Cultural Risk	10	1	3
Economic Benefit	107	108	58
Economic Risk	119	54	16
Environmental Benefit	179	197	253
Environmental Risk	119	66	12
Political Benefit	32	24	12
Political Risk	5	0	0
Regulatory & Legal Benefit	30	10	12
Regulatory & Legal Risk	32	10	3
Technical Benefit	9	41	17
Technical Risk	36	46	5
Total Number of References	678	557	391

A2: Table with the percent (%) references corresponding to each frame per region

SPEED Frame	North America	Europe	Middle East
Cultural Benefit	0%	0%	0%
Cultural Risk	1%	0%	1%
Economic Benefit	16%	19%	15%
Economic Risk	18%	10%	4%
Environmental Benefit	26%	35%	65%
Environmental Risk	18%	12%	3%
Political Benefit	5%	4%	3%
Political Risk	1%	0%	0%
Regulatory & Legal Benefit	4%	2%	3%
Regulatory & Legal Risk	5%	2%	1%
Technical Benefit	1%	7%	4%
Technical Risk	5%	8%	1%

A3: Plot with the percent (%) references corresponding to each frame per region



A4: Full quotations utilised in results and discussion (i*n order as they appear in the text*)

North America

Author	Newspaper	Year	Full Reference
Heesu Lee	Bloomberg and Financial Post	2021	the technology is the ticket to driving down emissions that will "allow Canada to achieve its ambition of getting to net zero by 2050" (*Mark Little, CEO of Suncor*)
Laura Legere	Pittsburgh Post-Gazette	2020	some heavy industries, like cement, unavoidably release carbon dioxide in the manufacturing process, so the only way to reduce their emissions is to capture it (*Kristin Carter, assistant state geologist of the Pennsylvania Geological Survey*).
John Cox	The Bakersfield Californian	2023	Little was said about the more controversial aspects that have made the activity a target for local environmental justice groups that argue carbon capture and sequestration presents asphyxiation risks and amounts to a taxpayer handout to the oil industry
Chris Varcoe	Sherwood Park News	2021	CCUS developments would allow the oilsands to potentially reach net-zero emissions and generate "low-cost, low- risk, low-carbon" oil (*Sonya Savage, Energy Minister*)
Michele Jarvie	The Calgary Herald	2023	Unfortunately, the vague and poorly implemented changes to the Competition Act only add unnecessary risk and more delay to the fundamental goal of cutting emissions and transitioning to a more sustainable future.

Europe

Author	Newspaper	Year	Full Reference
No author listed	Global LNG Monitor Today	2022	Mark Hatfield, told Upstream this week that the Gorgon CCS project is providing his company with "key learnings, which we continue to share with industry and government to assist in the development of this critical emissions-reduction technology" (*Mark Hatfield, Chevron Australia's Managing Director*)
Daniel Wetzel	Die Welt am Sonntag	2022	The focus of the offer is on CO_2 emissions that cannot be avoided in the production process, as is the case with cement production. "To achieve our climate targets, we need to invest in renewables and especially hydrogen, but we also need to offer a solution to industries in Germany that need to capture and recycle their CO_2 emissions," says Jörg Bergmann, spokesman for OGE's management. "To do that, we need a CO_2 infrastructure."
Caroline Dougherty	Irish independent	2023	"It's really important not to stumble into a discourse or a narrative that carbon capture and storage is coming and it's going to get cheaper so we don't have to worry too much about getting rid of fossil fuels." The disinformation tends to overlook the fact that around the world there are very few CCS installations in operation, and even fewer completely successful examples.(*Professor Barry McMullin, Dublin City University*)
Allister Thomas	Aberdeen Evening Express	2022	The Scottish Cluster alone, deploying CCUS, hydrogen and direct air capture technologies, could support an average of more than 15,000 jobs between 2022-2050, he added, with a peak of 20,600 in 2031, enough to kickstart a "whole new on and offshore industry". (*Michael Matheson*)
No author listed	Global Capital Euroweek	2022	Since the technologies are not yet proven at large scale, they could turn out to be building castles in the air. Such hopes might reduce the pressure to cut emissions at source.
Mike Tholen	The Scotsman	2021	A report published at the end of May from Aberdeen's Robert Gordon University highlights the transferability of oil and gas workers skills to adjacent energy sectors and predicts there could be as many as 200,000 jobs in 2030 for the offshore energy workforce. Continued investment in and support of the greener energies being developed by our industry will enable a managed transition of the tens of thousands of oil and gas workers into the broader offshore energy workforce.
Mark Williamson	The Herald	2021	To revitalise the birthplaces of the first industrial revolution, the UK will be at the global forefront of carbon capture, usage and storage technology, benefiting regions with industries that are particularly difficult to decarbonise, said the Government at the time.

Middle East

Author	Newspaper	Year	Full Reference
No author listed	Oman Daily Observer	2024	'OQGN with its partners is collaborating, conceptualising and developing hydrogen and CCUS pipeline infrastructure in line with Oman Vision 2040 and Oman's Net-Zero Emissions target by 2050,' it said. (*it = Memorandum of Understanding*)
No author listed	The Peninsula	2021	CCS traps emissions and buries them underground. Advocates of the technology see it a key to unlock large-scale economic hydrogen production, while critics say it will extend the life of dirty fossil fuels.
No author listed	Gulf Times	2023	In North Dakota, South Dakota, Iowa, and Illinois, however, the companies have had their permit applications rejected, or have had to slow work due to concerns from landowners along the proposed routes about safety and impacts to farms.
No author listed	Muscat Daily	2023	Petroleum Development Oman (PDO) has launched a pioneering pilot project for enhanced oil recovery (EOR) using CO2 in northern Oman, marking a significant step towards sustainable oil and gas production in alignment with the sultanate's goal of net-zero carbon emissions by 2050.
No author listed	Middle East Oil & Gas Monitor	2020	Enhanced oil recovery (EOR) is also at the forefront of the Middle East's carbon, capture, utilisation and storage (CCUS) push, with the circular carbon economy firmly in the sights of NOCs Saudi Aramco and ADNOC.
Sebastian Castelier	Haaretz	2021	"Carbon is not the enemy .... with the circular carbon economy, carbon will be an opportunity," Saudi Arabia's Energy Minister Prince Abdulaziz bin Salman bin Abdulaziz said in 2019.
No author listed	Saudi Gazette	2024	He stated that Saudi Arabia seeks to enhance its efforts to achieve its ambitious goal of reaching net zero by 2060 through the Circular Carbon Economy Framework, which not only reduces the impact of carbon emissions but also values carbon as a resource with real economic value, rather than a pollutant.
No author listed	Saudi Gazette	2020	"Reuse" refers to converting emissions into value-added materials to industries by utilizing and advancing carbon capture and utilization (CCU), and emissions to value (E2V).
No author listed	Saudi Gazette	2021	The workshop participants emphasized that the downstream industries based on the Kingdom's access to low-cost, low-carbon oil production provide another area for green growth. The petrochemical industry could increase its use of renewable energy and improve its efficiency, allowing the Kingdom to position itself as a supplier of low-carbon basic petrochemicals as well as higher-value specialty chemicals and materials.

Quotes conflating CCUS technologies

Author	Newspaper	Year	Full Reference
No author listed	North American Oil & Gas Monitor	2022	Carbon capture and storage (CCS) development is picking up pace, in the US and globally. The technology, also known as carbon capture, utilisation and storage (CCUS), has been around for some time
Andrew Adams	Pantagraph	2023	Carbon capture is a method whereby carbon dioxide, a common greenhouse gas, is placed in long-term storage, usually by injection into wells in geologic formations thousands of feet underground. These wells take advantage of empty ”pore space” in subsurface structures. It is sometimes referred to as carbon capture, utilization and sequestration, or CCUS.

A5: Quotations from North American articles relating to SPEED frames.

SPEED Frame	Benefit	Risk
Technical	Our province's fortunate geological situation once again gives Alberta a natural advantage, this time in CCUS. Alberta and Saskatchewan could safely store decades' worth of North America's carbon emissions, making Alberta ideal for carbon storage (*Bill Mah, Edmonton Journal, 2024*).	To complicate things, there are already "so many things going on" underground here: historical and current coal, oil and gas extraction, natural gas storage fields and the potential to store natural gas liquids (Kristin Carter, assistant state geologist of the Pennsylvania Geological Survey) (*Laura Legere, Pittsburgh Post-Gazette, 2020*).
Economic	Carbon capture projects are a proven and near-term investment opportunity that can create direct and indirect jobs - all while achieving large emission reductions (*Michael Morrison, The Calgary Herald, 2020*).	Washington intends to throw money at virtually every idea that has a reasonable shot at helping the U.S. get to net zero, including costly carbon sequestration projects, a favourite of Canada's oil majors, who argue the technology must be part of any realistic shift to carbon neutrality, even though no one has yet proved it works at scale (*Meghan Potkins, Post Media Breaking News, 2022*).
Political	Large scale support for CCUS is critical for meeting Canada's long term energy needs and climate goals (Sonya Savage, Environment Minister) (*Matthew Black, Post Media Breaking News*)	Another important qualification, and a point seized upon by industry players, is that the analysis does not reflect how private companies perceive the political risk to carbon pricing in the future without further guarantees from governments (*Meghan Potkins, Post Media Breaking News, 2023*).
Regulatory & Legal	the U.S. House of Representatives passed the Inflation Reduction Act that widened incentives for capturing and storing carbon dioxide and introduced new tax credits for producing hydrogen with low or no carbon impact (*Anya Litvak, Pittsburgh Post-Gazette, 2022*).	However, few projects have received the green light as companies have been waiting for final investment tax credit program details and necessary federal funding to back it up (*Chris Varcoe, Calgary Herald, 2023*).
Environmental	With cement demand on the rise and as a sector that is challenged with further abating emissions, large-scale CCS could well become the definitive solution to cut GHGs (*The Financial Post, 2021*).	It's uneconomical and environmentally irresponsible to keep burning coal for electricity generation, no matter how much tax revenue it brings to Wyoming. It's killing our planet (*The Wyoming Tribune, 2022*).
Cultural	None present.	Farmers, too, are less than enthusiastic about granting Summit pipeline easements, no matter its size or depth, across their land (*Alan Guebert, Telegraph Herald, 2023*)

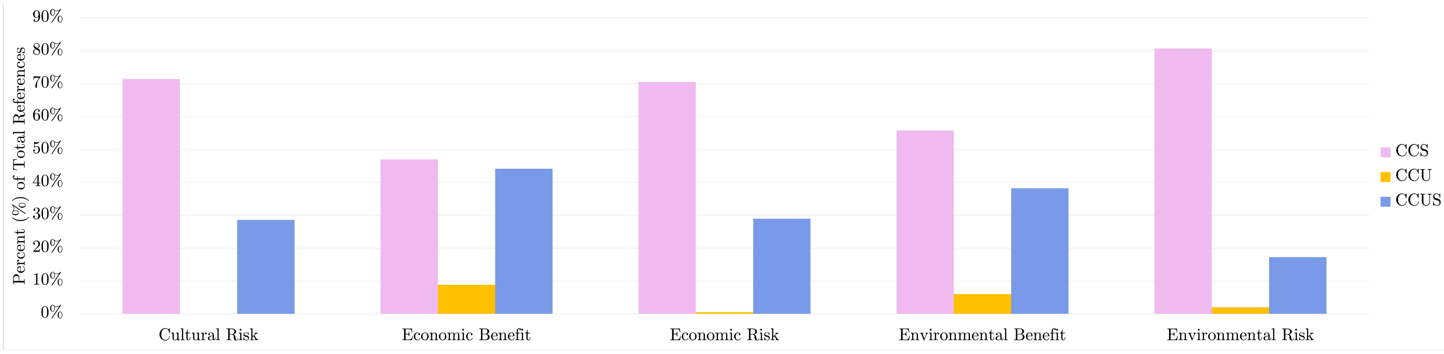
A6: Quotations from European articles relating to SPEED frames.

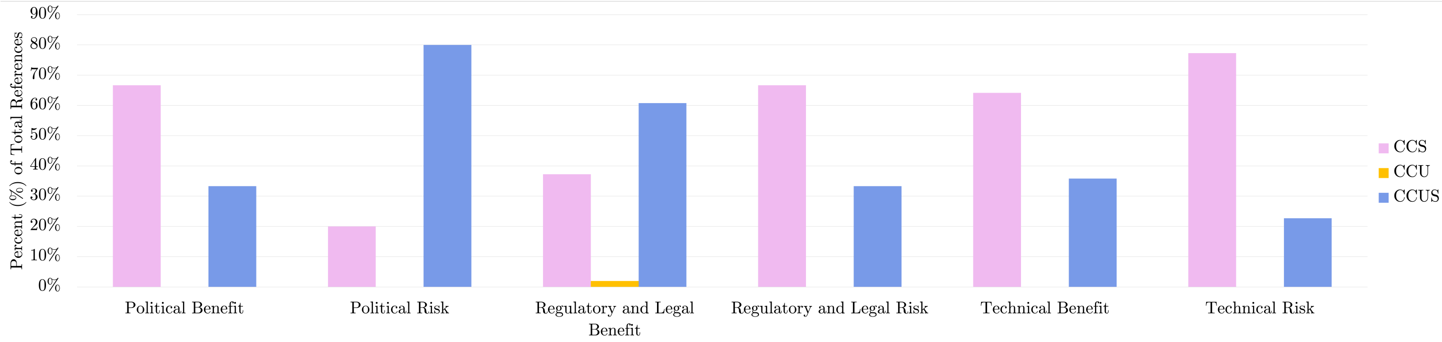
SPEED Frame	Benefit	Risk
Technical	"These assets are already there, while drilling [new] boreholes is very expensive and adds a certain amount of risk. The range of boreholes we have will also give opportunities to test different rock types." (Professor Richard Davies from University of Newcastle) (*Tim Wyatt, The Independent, 2021*)	Demonstrating that stores can capture CO_2 and hold it for the long term is another challenge for the industry. There are, as yet, no insurance products in the UK covering this eventuality (*Ed Reed, The Press and Journal, 2023*).
Economic	The Scottish Government has put £80 million on the table to accelerate a carbon capture and storage project that may create thousands of north-east jobs - and called on the UK Government to back it (*Erikka Askeland, Aberdeen Press and Journal, 2022*).	Although CCS has been successfully put into practice at around 20 large-scale projects around the world, it remains a new technology and for now fairly expensive also (*Tim Wyatt, The Independent, 2021*).
Political	With the Government providing up to £20 billion of funding for early deployment of CCS, the Prime Minister explained how this was "new technology that Britain can lead the world in", and he was "incredibly excited" about it (Rishi Sunak, Prime Minister UK) (*Daily Post, 2023*)	None present.
Regulatory & Legal	"The biggest risks with CCS are financial, rather than technical," he said. "Costs of CCS will fall over time as we scale up. But the government could accelerate this process by raising carbon prices and giving investors a clearer signal on their long-term trajectory" (Simon Virley, lead energy partner at KMPG UK) (*Jamie Smyth, Financial Times*)	Frequent policy U-turns from the last government have not helped, slowing development and the scale-up that would have brought down costs (Laith Whitwham, Senior Policy Advisor at E3G) (*Jonathan Leake, The Telegraph, 2024*).
Environmental	Indeed, consultancy IHS Markit has said that if emissions from these fields are to be managed, then CCS will be key. It has estimated that CCS could reduce emissions from the Kasawari field by around 46mn tonnes over the field's operating life (*Global LNG Monitor Today, 2022*).	Unproven Carbon Capture Utilisation and Storage (CCUS) is enabling dirty fossil fuels to be reconsidered as 'green' (*David Bricknell, The Plymouth Herald, 2023*)
Cultural	None present.	"Implementation of CCS currently faces technological, economic, institutional, ecological, environmental and sociocultural barriers" (*Camilla Hodgson, Financial Times, 2023*)

A7: Quotations from Middle Eastern articles relating to SPEED frames.

SPEED Frame	Benefit	Risk
Technical	Building on ADNOC's Al Reyadah facility, which has the capacity to capture up to 800,000 tons of CO_2 per year, the company will announce plans to deploy technologies to capture, store and absorb CO_2 by leveraging the UAE's geological properties while preparing for its next major investment to capture emissions from its Habshan gas processing facility (*Bahrain News Agency, 2023*).	Critics argue that CCUS are smokescreens intended to maintain the status quo: Carbon sequestration and similar techniques remain unproven and expensive. "It is a false solution," Stockton says. "The fossil fuel industry talks about this technology as if it is perfect all the time, but it underperforms, leaks, breakdowns and does not hit targets." (*Sebastian Castelier, Haaretz, 2021*)
Economic	He (*Saudi Arabian Minister of Energy, Prince Abdul Aziz bin Salman*) also indicated that the Kingdom, in line with this vision, and to exploit the economic value of carbon worldwide, has launched, in partnership with leading organizations, a global carbon capture and utilization challenge (*Saudi Gazette, 2024*)	The technology is still in the early stages, and has been slow to develop because of prohibitive costs – compared to the price companies have to pay for CO_2 emission quotas, for example. It therefore depends heavily on subsidies (*The Peninsula, 2024*).
Political	The minister (*Minister of Energy, Prince Abdul Aziz bin Salman*) highlighted Saudi Arabia's leadership in Carbon Capture, Utilization, and Storage (CCUS) technologies, reiterating the Kingdom's commitment to leading global efforts through its adoption of circular carbon economy technologies (*Saudi Gazette, 2024*)	None present.
Regulatory & Legal	Oman's Ministry of Energy and Minerals has pledged to work closely with early adopters of Carbon Capture, Utilisation and Storage (CCUS) technologies in the formulation of a regulatory framework and underlying policies governing this promising new industry (*Oman Daily Observer, 2023*)	"You do need some policy stability for these large, capital-intensive projects to happen. We have some 27 projects (around the world), we need to go over 100 by 2035. The means to do that is there, we just need the policies in place to stimulate," he said (Mr Tim Dixon, General Manager of IEA Greenhouse Gas R&D Programme) (*Qatar Tribune, 2022*)
Environmental	"If we are to have any hope of keeping global temperature [increases] down below 2°C then we desperately need to develop ways to capture and store carbon dioxide." (Professor Stuart Haszeldine, of Edinburgh University, UK) (*Iran Daily*)	CCS traps emissions and buries them underground. Advocates of the technology see it a key to unlock large-scale economic hydrogen production, while critics say it will extend the life of dirty fossil fuels (*The Peninsula, 2021*)
Cultural	None present.	Public support and community engagement are crucial in ensuring that CCUS technologies can be scaled effectively. "To truly scale CCUS, we must move beyond gaining acceptance to establishing trust. Projects need to be credible, legitimate, and something that society feels a part of. A social license to operate is essential for the energy transition" (Professor Mercedes Maroto-Valer, Director UK industrial Decarbonisation Research and Innovation Centre) (*Gulf Times, 2024*)

A8: Co-occurrence of SPEED Frames and CCUS, CCU, and CCS





Research Data Management Plan

1. Data Collection

1.1 Type of Data	Newspaper articles derived from Nexis Uni data base — qualitative codes that arose from the data
1.2 Format	PDF and .xlsx

2. Data Storage and Back-up

2.1 Data Documentation	100 articles per region were obtained in PDF format from the Nexis Uni Database. They are labelled by the number of articles in the batch and region (e.g. Europe (1-500)). The codes are in an .xlsx file.
2.2 Primary and Intermediary Data Information	The primary data is in the appendix, and the processed data is in the report as well as an attached .xlsx file named "ATLAS TI Views".
2.3 Name and Location of Data	PDF files of the coded articles and the produced codes are in a file on my personal laptop, and will be sent to Paul Upham.
2.4 Back-up Strategy	Automatic backups.
2.5 Is data in Y-drive before handing out thesis?	No

3. Data Access and Ownership

3.1 Privacy and Security	The data is not sensitive, thus no protection was needed
3.2 Accessibility	Paul Upham will have access to the data