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A strategic insight into the market for carbon management capacity

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ABSTRACT

This study presents the market for *carbon management capacity* via carbon capture, utilization, and storage technologies, identifying demand and supply forces, as well as clarifying the potential impact of market and non-market-based shocks on technology developers versus adopters. The paper addresses a prevailing gap in market analysis, introducing a microeconomic framework and unique dataset to identify key players, market forces, and policy incentives shaping the carbon capture, utilization, and storage landscape. The analysis equips industry stakeholders, policymakers, and investors with valuable insights regarding (1) leaders in the design, development, and manufacture of carbon capture, utilization, and storage technologies (supply), (2) early technology adopters (demand) who are at the forefront in the pursuit of sustainable carbon management, and (3) the need to use *both* market and non-market forces to achieve decarbonization across multiple sectors.

1. Introduction

Increasing global interest in carbon capture, utilization, and storage (CCUS) stems from its significant potential to reduce CO_2 emissions, particularly in energy-intensive sectors [40]. Although CCUS is sometimes presented as an integrated climate solution, it involves multiple technologies uniquely developed to manage CO_2. These technologies begin with capturing CO_2 (e.g., from air or industrial emissions), then transporting and storing it underground (e.g., in depleted oil fields or saline aquifers) [19,28]. It also includes converting CO_2 into usable inputs for industrial processes. Carbon capture and utilization (CCU) generates economic value by reducing emissions [22], while carbon capture and storage (CCS) focuses on long-term storage, both enabling decarbonization across sectors [32].

Over the last three decades, CCUS technologies have advanced significantly, showing efficient ways to capture and manage industrial CO_2 [8,37]. For example, there are improved methods for separating CO_2, and innovations in mapping potential storage sites [13]. Research and development (R&D) has led to new uses for captured CO_2 in industrial applications [24,27]. However, several studies show significant investment is needed for CCUS infrastructure, such as retrofitting facilities, building transportation pipelines, and identifying safe storage sites [2]. Some studies suggest that under certain conditions, CCUS could be cost-competitive with other low-carbon technologies. For example, Nakaten et al. [25] show CCS could be economically feasible compared to other low-carbon electricity production options. Philbin and Wang [28] find that while CCS increases costs for natural gas and coal-fired plants, these premiums are still lower than those for renewable technologies like solar. Additionally, Budinis et al. [3] argue that CCS can be a cost-effective option in the long term.

Although CCUS is a promising climate solution, its commercial adoption rate remains low due to weak returns on investment. According to the Global CCS Institute, fewer than 400 large-scale CCUS facilities exist worldwide, with most still in development [14]. Chen et al. [4] argue that challenges such as deployment uncertainties, regulatory gaps, and the lack of risk-sharing mechanisms may delay large-scale CCUS adoption until 2040–2060. Based on 263 CCUS projects, Wang et al. [35] find that scaling is hindered by imbalanced risks and returns which may continue to slow CCUS adoption. Several studies emphasize the need for policy support for large-scale CCUS adoption [15]. Azure et al. [2] and Colombe et al. [6] highlight the role of subsidies and tax credits for power generators to invest in CCS. Yang et al. [38] propose a non-subsidy-based incentive model for China, suggesting that increasing production quotas for coal-fired generators could help offset investment costs by boosting power output. Aune et al. [1] advocate for subsidies targeting CCS technology developers rather than adopters in Europe.

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Krahé et al. [18] call for a flexible, integrated policy framework to facilitate CCUS deployment and private investment. Wang et al. [35] argue for greater policy support and carbon pricing to increase project scaling. Pingkuo and Jiahao [29] explore how reducing carbon allowances and raising carbon prices can incentivize CCUS investment in CO_2-intensive sectors.

Given the capital intensity of CCUS, financial viability requires policy incentives to reduce the financial burden on industries, along with carbon pricing to address negative externalities [39]. However, designing and implementing such policies requires understanding CCUS market dynamics and the channels through which policies affect investment decisions. Despite increasing interest in the economic feasibility of CCUS, there is a lack of comprehensive market analysis assessing current and potential stakeholders in the supply chain, largely due to limited market data on these key players. We fill this gap by adopting a microeconomic framework to analyze market forces related to the *supply and demand of carbon management capacity*. In Section 2, the market framework is used to examine the role of market and non-market forces in increasing carbon management capacity through CCUS. In Section 3, we present a unique dataset on leading global market players in the carbon management space. Understanding market dynamics will aid industry participants, policymakers, and investors in scaling CCUS technologies to reduce carbon emissions and support a sustainable economy.

2. Adopting the demand-supply model for carbon management capacity

Using the demand-supply model [24], we analyze the market for carbon management capacity influenced by market and non-market factors. This framework is commonly used to predict climate policy impacts on market outcomes [10,11,33].

2.1. Supply of carbon management capacity

Our supply definition aligns with pollution abatement [17] but differs from CO_2 supply for CCUS operations [24]. We define *supply* as resources, expertise, and infrastructure enabling CO_2 management technologies. This includes CCUS technologies for capturing, storing, or utilizing CO_2. Supply chains span from R&D to commercial production of equipment like carbon filters and infrastructure like pipelines.[1] Supply is viewed as *physical capital* that can be purchased and adopted by downstream industries at a given price (e.g., dollar per capacity) to achieve carbon management goals [17]. It depends on specialized resources (e.g., labor, solvents) and systems with high marginal opportunity costs (e.g., patented processes or reagents) [20].

In addition, there are currently few private agents (e.g., mostly startups or small-scale labs) actively involved in the discovery and production of technologies that enhance carbon management capabilities (e.g., Canada-based *Svante* develops and manufactures carbon filters), some of which are still in R&D (e.g., low commercial readiness). Even when CCUS technologies are technically demonstrated [8,37], companies face financial and scalability barriers (e.g., high cost of entry, tech-intensive), uncertain demand, evolving regulatory dynamics, and the challenges surrounding the need to have synergetic infrastructure.[2] This means carbon management solution providers (e.g., producers of carbon filters) may not be able to rapidly change their production volumes (e.g., scale up) at the same proportion in response to market prices and/or changes in demand (if any). Economists refer to this as a less elastic supply which means the quantity of carbon management capacity supplied to the market is less responsive to price changes [16]; and it is mainly attributed to the capital intensity of production and high production costs (e.g., in the context of natural gas production Mason and Roberts [21] find that supply price elasticity increases or improves with new, more advanced technologies).

Fig. 1 illustrates the initial supply (solid line) as less elastic compared to future supply (dotted line), similar to Naims [24]'s stepwise increasing marginal cost model. The figure shows that future carbon management supply could grow and become more elastic (i.e., responsive to price changes). First, is the impact of policy incentives that are directly instituted on the supply side. This includes R&D support, grants, and loans for private agents to invest more in discovering innovative and cost-effective CCUS processes and technologies (e.g., subsidies or tax credits). It also requires addressing non-financial barriers for new companies to take on risky investments. For instance, a supporting regulatory framework provides clearer guidelines for developing technologies or raising capital (e.g., purchase commitments and financial risk management tools). Such actions could increase the number of technology developers thereby improving market competition, allowing for alternative advanced technological innovations, and potentially reducing the marginal cost of enhancing carbon management capacity. This could allow for more flexible carbon management capacity in response to market shifts. Second, market-driven solutions can improve carbon management supply by raising capital, prioritizing sustainability as a corporate goal (e.g., carbon offset initiatives), and forming partnerships. For example, *Heirloom Technologies*, based in California became the first US commercial direct air capture facility due to California's carbon removal credit system and customer interest (e.g., Microsoft) in purchasing carbon removal credits.

A combination of policy-induced and market solutions can increase supply as depicted in Fig. 1. This reduces the per-unit cost of improving capacity, leading to higher demand for carbon management (represented by the golden arrow), which can be met by CCUS technologies. Downstream industries, such as power generators, could then access greater carbon management capacity at lower costs.

2.2. Demand for Carbon Management Capacity

Once CCUS technologies become commercially viable, downstream industries can purchase them as *physical capital* if market, institutional, and policy infrastructure are in place [24]. Demand for carbon management capacity comes from industries seeking to increase their carbon management capacity via CCUS technologies. For instance, fossil-fuel power generators may adopt CCS while cement and concrete manufacturers may opt for CCU [5,12,23].

The demand for carbon abatement is driven by market returns and government policies [7,34]. Currently, there are limited monetization opportunities for adopting CCUS outside of subsidies [35]. For instance, Azure et al. [2] illustrate that in the U.S., tax credits are the primary incentives for CCS investment. In contrast, renewable energy investments benefit from both tax credit and additional price premiums (e.g., green electricity markets). Edmonds et al. [9] predict that tax credits,

[1] For example, *Carbfix* (an Iceland-based company) provides CCS retrofits and related services to industries located near a favorable rock formation. Another example is *CarbonCure* (based in Canada) which supplies a retrofit technology that allows concrete manufacturers to capture their carbon emissions and re-use them to make greener and stronger concrete. *Summit Carbon Solutions* (based in the US) offers capture and transportation infrastructure to ethanol producers in the mid-west, where captured CO_2 either ends up in geological formations or is used in enhanced oil recovery (EOR).

[2] For instance, while discovering efficient CO2 capture methods is important, it is insufficient on its own. A comprehensive infrastructure for transporting and storing captured CO2 is essential, along with advancements in other areas such as pipeline networks, storage facilities, and monitoring systems.

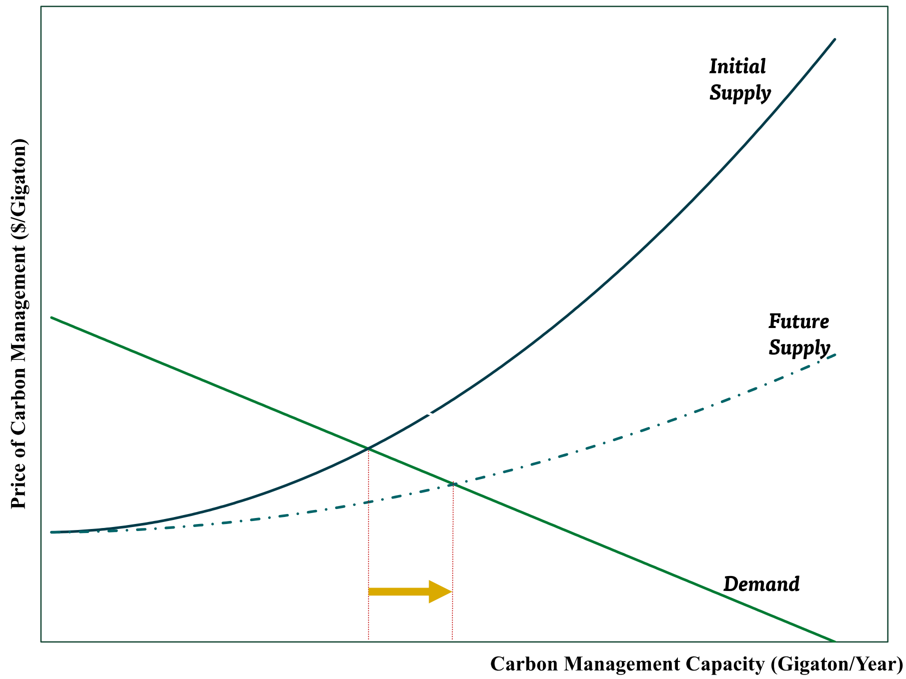

Fig. 1. Increase in supply of carbon management capacity.

like those in Section 45Q of the US tax code, could accelerate CCUS investments in the power sector. Ochu and Friedmann [26] argue that without clear regulations and generous policy incentives to close the financing gap, carbon-intensive industries may not adopt CCUS at the necessary scale for decarbonization goals.

Thus, the primary source of demand for carbon management among downstream industries comes from incentive-based environmental policies and regulations that price carbon, either implicitly or explicitly, as well as command-and-control regulations for carbon management [17, 34]. Fig. 2 summarizes demand-side policies that create or increase demand for carbon management in the absence of market forces. While incentive-based approaches offer financial motivation to reduce CO_2 either through a carrot (e.g., subsidy) or stick (e.g., emission tax) approach, command-and-control approaches set performance targets (e.g., capture thresholds, emission standards) or mandate-specific technology (e.g., CCS). The Section 45Q tax credit of the U.S. Inflation Reduction Act (IRA) is an example providing a tax credit of $85/ton for CO_2 storage, $60/ton for CCU, $180 for DAC with storage, and $130 for DAC with CO_2 use [36].

Environmental policies are essential for CCUS adoption and studies show the effectiveness of using a mix of policies rather than picking one [39]. First, when market forces are weak, government support can be used to accelerate results. In the CCUS context, high upfront costs and limited monetization options beyond subsidies deter adoption. Second, carbon trading and carbon taxes offer industries flexibility in cost-effectively achieving compliance through cleaner production or CCUS. For example, Chen et al. [5] show that while both carbon pricing and abatement subsidy make CCUS feasible, carbon pricing has a lower fiscal burden. Third, while command-and-control approaches can be costly [17], they can act as a preliminary step for technology adoption (e.g., carbon capture quotas for high-emission plants). For instance, the US state of Wyoming proposed mandating coal-based plants to consider CCUS, though concerns remain about passing costs to customers (Wyoming bill 22LSO-0357, Wyoming bill 23LSO-0258). In addition, legal and regulatory frameworks can be improved to speed CCUS adoption among carbon-intensive industries. For example, US states like Indiana and Wyoming are enacting legislation to shift long-term liabilities and risks to the state.

Favorable market conditions or enhanced/new policy incentives could increase demand for carbon management as in Fig. 3 creating a new market equilibrium with higher carbon management levels. Policies affecting supply, like R&D subsidies, lower the cost of innovation, while demand-side policies, such as tax credits for emitters (e.g., Section 45Q), increase adoption. As Fig. 3 suggests, the increase in either or both demand and supply affects per unit costs. For instance, if policies are only instituted on the demand side with no commensurate policy impacting supply, prices could rise, making it expensive for industries to adopt CCUS. This highlights the importance of targeting both demand and supply forces to achieve cost-effective decarbonization.

3. Identifying key players in the market for carbon management

This study uses a pair of unique datasets to identify and characterize key players contributing to the supply and demand for carbon management at a global level. While studies present technical aspects of CCUS, including techno-economic analysis [13,27,37], limited studies identify market players.[3] Moreover, despite a growing number of studies evaluating the impact of policies on CCUS [5,7], none identify the market players leading technology development and adoption. We identify market participants actively shaping CCUS supply and demand dynamics.

3.1. Identification of supply forces

We use our institutional subscription to *PitchBook Inc.*, a database of global capital markets, to characterize companies involved in CCUS or closely related sectors. Since there is no specialized industry classification for such companies, we use text analysis to identify the *supply of carbon management capacity*. See the Appendix for details on sample selection.

There is a total of 167 companies (*CCUS suppliers*, henceforth) whose

[3] Among the limited studies is Naims [24], which uses the demand-supply model to identify CO2 emitting sources as providing carbon supply for CCU applications. Demand for CO_2 comes from various sectors that utilize carbon as a feedstock (e.g., the food and beverage industry, EOR, and different chemical and fuel producers).

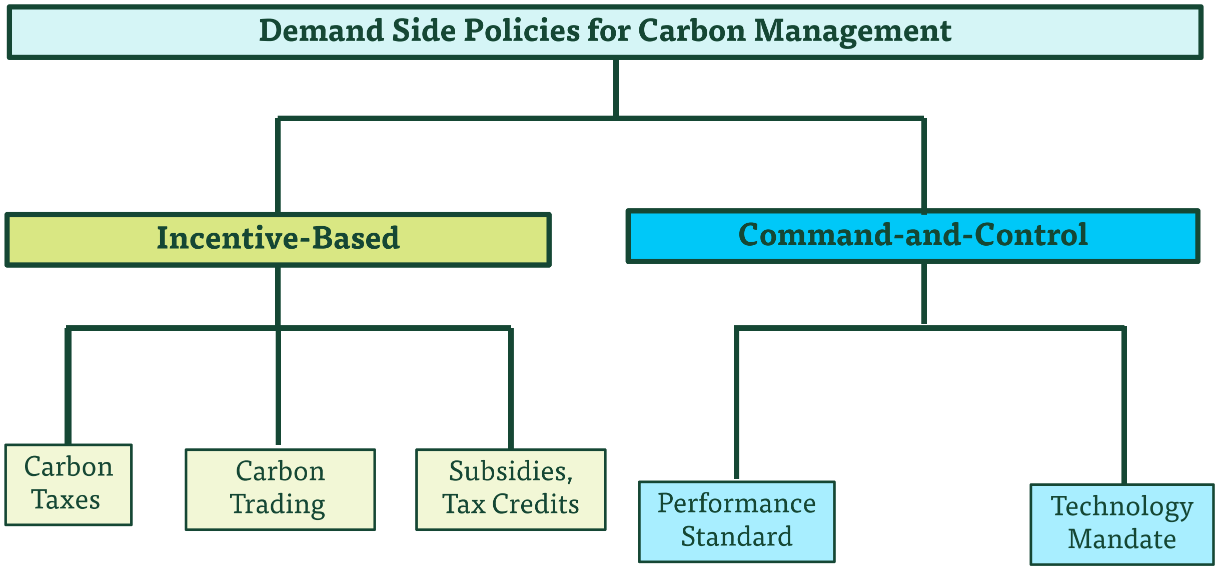

Fig. 2. Policies for increasing demand for carbon management.

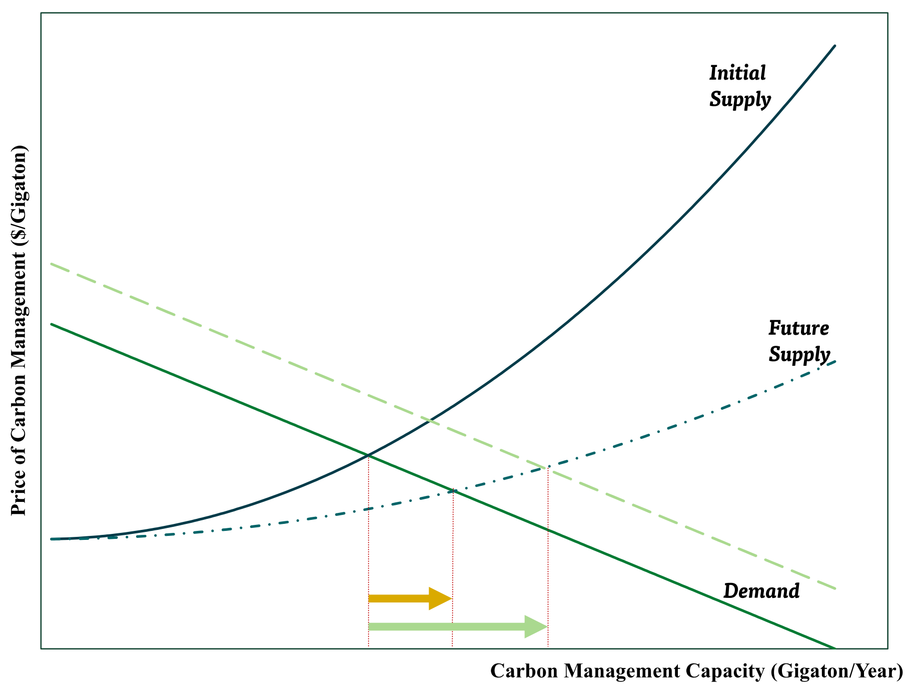

Fig. 3. Increase in demand and supply for carbon management capacity.

business description fits the supply of CCUS or related services. We manually analyze their business descriptions to ensure they are involved in the supply of CCUS technologies or related services. Fig. 4 provides a word cloud, based on a text analysis of the company descriptions of the 167 CCUS suppliers. The prominence of the word "carbon" highlights the central focus on reducing CO_2 emissions. The word frequencies also emphasize a technology-driven, business-centric approach (e.g., words like "company", "developer", and "products") to developing CCUS technologies, with a focus on reducing emissions in the "energy" and "industrial" sectors. There is also a notable emphasis on innovation and commercialization, as evidenced by references to "services" and "clients" (e.g., CCUS technologies developed and marketed as services or solutions for businesses seeking to reduce their carbon footprint). The word "capture' suggests that most of the companies are focused on developing technologies related to carbon capture, among others. Furthermore, the presence of words like "renewable" and "hydrogen" (although unexpected) suggests that carbon capture technologies are being integrated with broader clean energy and decarbonization efforts. Terms like "designed" and "intended" highlight the purpose-driven nature of these technologies. The frequent use of "enabling" suggests the importance of enabling mechanisms, such as tools, platforms, or services that help reduce carbon emissions.

3.1.1. CCUS suppliers versus energy transition technology suppliers

Table 1 presents a comparison of the 167 companies with other companies involved in energy transition technologies (ETT), such as renewable fuel producers found in the *Pitchbook Inc*. database. See the Appendix for methods used to identify ETT suppliers. For both groups of companies (CCUS suppliers, ETT suppliers), we use *PitchBook* to collect data on the (1) number of employees, (2) total raised capital, and (3)

Fig. 4. Word cloud of company description of 167 CCUS suppliers.

Table 1
Test of mean differences between ETT and CCUS suppliers.

	ETT suppliers	CCUS suppliers	P-values
Employees (number)	Mean=1558 SD=20,385 N=814	Mean= 39 SD=92 N=167	p = 0.336 (equal variance) p = 0.0338 (unequal variance)
Total raised (millions)	Mean= $125.19 SD=$483.33 N=814	Mean= $36.25 SD=$93.82 N=167	p = 0.018 (equal variance) p = 0.000 (unequal variance)
Web growth rate (%)	Mean=0.169 SD=1.485 N=534	Mean =0.33 SD=1.996 N=141	p-value = 0.288 (equal variance) p-value = 0.366 (unequal variance)

company web growth rate. Web growth rate is documented as a key non-financial growth signal and proxy for company growth and social traction based on web or online presence and "social reach". The web growth rate measures "the average weekly growth rate over eight weeks" [30,31]. Together, these three metrics capture both the financial health and market positioning of the company, helping identify leaders in the sector. For example, the number of employees measures operational capacity, total raised capital reflects investor confidence and financial strength, while the web growth rate provides insight into market visibility and engagement.

Table 1 presents a comparison of mean tests for the two groups of companies, with and without the assumption of equal variance, using the two-sample *t*-test where the null hypothesis presents equality of means. The mean test assumes the samples are independent and data is normally distributed. See the appendix for a comparison of medians and equality of distribution tests as robustness checks.

Employees: The two-sample *t*-test with unequal variance indicates that CCUS suppliers have fewer employees on average (39 workers) compared to ETT suppliers (1558 workers), whereas the mean test with equal variance does not yield statistically significant differences. This could suggest that CCUS suppliers are smaller than ETT suppliers in the number of employees. The small size and operational capacity could be because the CCUS industry is newer and has a lower labor force compared to the market for energy transition or other low-carbon technologies.

Total Raised: The mean capital raised by ETT suppliers ($125 million) is significantly higher than that for CCUS suppliers ($36 million). The results indicate that ETT suppliers have higher financial backing and a stronger ability to secure funding. The lower value of capital raised by the average CCUS supplier illustrates the difficulty of raising money in industries that develop novel technologies. Capital raising can be challenging for CCUS because these technologies are still evolving, and there is less historical data on their costs, returns, and adoption rates. Investors may also perceive higher risks related to the technical and monetization aspects, which makes it challenging to raise capital. In comparison, low-carbon, or energy transition technologies (e.g., renewables) have matured over the years with demonstrated economic and market viability. Another potential reason why CCUS suppliers have found it hard to raise capital is due to limited or uncertain policy support towards CCUS relative to renewable technologies. Finally, investors may be more familiar with renewable energy than CCUS making it more challenging to attract capital for CCUS. Thus, market forces driving increased supply could be limited in the short run.

Web Growth Rate: We find that the sample of CCUS suppliers has on average, higher website traffic (0.33) compared to ETT suppliers (0.169). However, this difference is not statistically significant. Even when CCUS suppliers use digital platforms to raise awareness (e.g., among the general public or specific investors) and promote their advancements (e.g., carbon capture solutions to achieve climate goals), their online engagement efforts (e.g., resulting in more search traffic) are not necessarily higher than ETT suppliers who may also be undertaking similar activities.

3.1.2. *Business description of CCUS suppliers*

About 84% of the 167 CCUS suppliers were founded between 2010 and 2023. These companies raised a gross amount of $6055 million and hired a total of 6487 employees across the globe. Most of the 167 businesses (83%) are fully operational/commercial generating revenue from the sale of their products/services, 6% are startups (N=10), about 3% are in product development or beta testing stage (N=7), and close to 6% are out of business (N=10). Their ownership structure is majority privately held (83%) with a few publicly held companies (7%), and a few acquired/merged or operating as a subsidiary (2%).

These companies are involved in various activities ranging from R&D, design, development (e.g., carbon capture, carbon removal, and DAC technologies), and manufacturing of equipment and devices, software development (e.g., monitoring carbon removal), to the provision of business-to-business (B2B) environmental services, and other platforms. Others provide services including the provision of engineering design services for carbon storage, or transport, carbon capture and mineralization services, R&D services, carbon removal and storage services, and carbon-negative alternatives. We use the company descriptions to isolate keywords that describe what the companies do, and the results, summarized in Fig. 5, show that 57% of the companies (N=96) are involved in developing products, platforms, systems, or technologies.

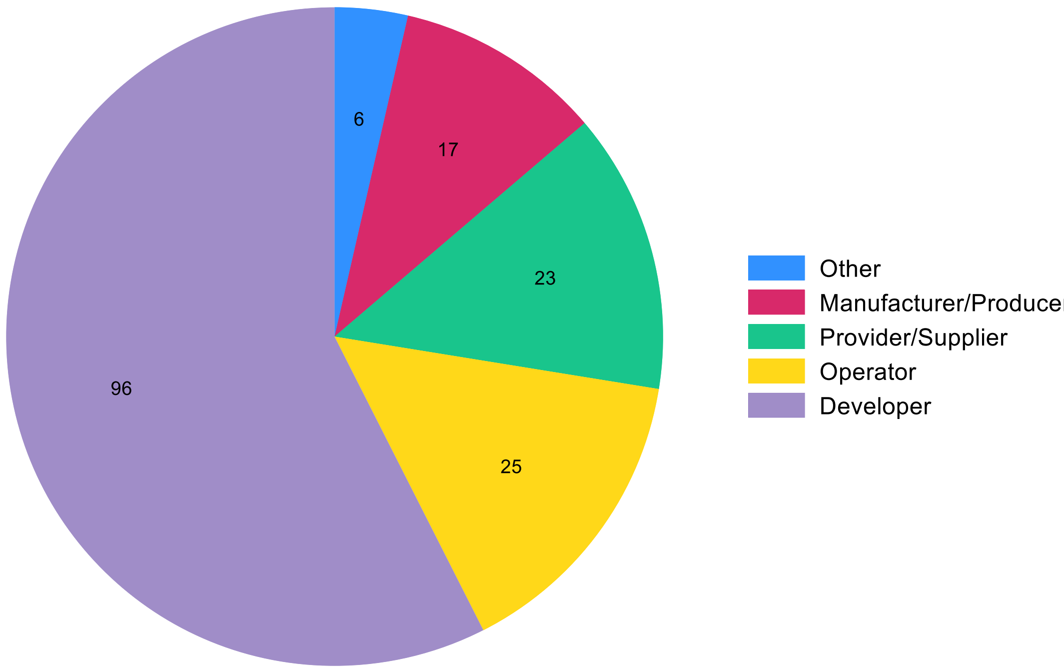

Fig. 5. Company description summary for what CCUS suppliers do (N=167).

About 15% are operators of a company, plant, or project (N=25), 14% providers of a service or suppliers of a product or service (N=23), while about 10% (N=17) are manufacturers.

3.1.3. Financial statistics of CCUS suppliers by location and industry groups

CCUS suppliers in our sample are headquartered in 26 different countries where a majority (72%) are found in the US (N=69), the UK (N=32), and Canada (N=19), followed by Norway (N=8) and Australia (N=5). The rest of the countries have one to three companies each. Fig. 6 shows that the US and Norway rank top in terms of total workers followed by the UK and Canada. The US remains the leader in this space ranking top for the number of companies and total employment size.

There are three core primary industry categories the companies are classified under in the *PitchBook* database, and these are (1) products and services (N=98) which are mostly B2B operations, (2) energy (N=37) which are involved in developing a fuel/energy technology, and (3) materials and resources (N=22) which are developers of technology or manufacturers of equipment. The other categories (N=10) represent firms providing specialized financial services to CCUS technology developers, firms in the biotech industry producing specialized CCUS equipment/processes using non-synthetic materials, and IT firms that provide specialized software and related services for carbon solutions.

The average company in the sample raised $36 million in capital with a range from $0.01 to $786 million, employed 39 workers on average (a range of 1 to 907), and exhibited an average web growth rate of 0.3% (range of -1.89% to 4.62%). As Table 2 shows, these statistics widely vary by location and industry group. Typically, larger companies with several employees can raise more money, and businesses in the energy sector have raised higher amounts on average compared to others, except the financial sector, which has only two observations. Regionwide, North America and Europe have companies with higher capital raised and employing more workers.

Figs. 7 and 8 present a ranking of companies based on number of employees and total capital raised, respectively. *Kongsberg Digital*, an industrial software developer based in Norway ranks top in the number of employees, followed by US-based *FuelCell Energy* focused on

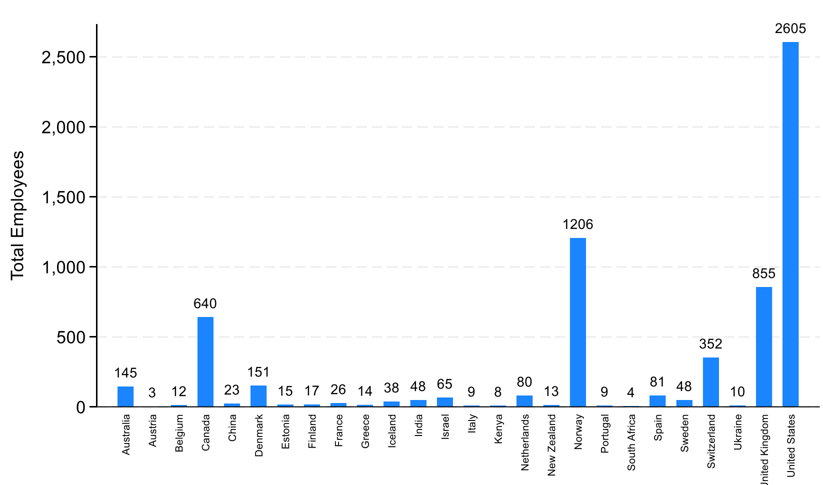

Fig. 6. Gross employment of CCUS suppliers by headquarters country.

Table 2
Mean values by industry category and headquarters.

Industry Category	Raised capital (million)	Web growth rate (%)	Employees
Products and services (N=98)	$39.54	0.50	36
Energy (N=37)	$43.55	0.10	43
Materials and resources (N=22)	$19.51	0.35	25
Financial Services[+] (N=2)	$225.00	0.00	4
Healthcare[++] (N=4)	$3.44	0.26	11
Information technology[+++] (N=4)	$35.60	0.21	260
Region			
Africa (N=2)	$0.74	0.86	8
Americas (N=88)	$48.16	0.42	40
Asia (N=3)	$1.06	-0.09	24
Europe (N=63)	$32.06	0.33	47
Middle East (N=3)	$14.14	0.41	22
Oceania (N=7)	$21.10	0.37	26

[+] *Climate Change Crisis Real Impact Corp* (US) is focused on facilitating M&As in the carbon removal industry. *Fortistar Sustainable Solutions Corp* (US) is also a special-purpose acquisition company focused on providing services for CCUS companies.

[++] These are biotechnology or pharmaceuticals: *DMF Medical Inc.* (Canada, manufactures carbon filtration device used in medical equipment), *Enzymit Ltd.* (Israel, develops platform where natural enzymes can be used in capturing and converting carbon), *CyanoCapture* (UK, develops carbon capture technology using genetically modified bacteria), and *Solmeyea* (Greece, operates an agri-biotech company using carbon utilization techniques).

[+++] *Dendra Systems Ltd.* (UK, develops reforestation technology), *Isometric HQ Ltd.* (UK, develops a platform to confirm carbon removal claims), *Kongsberg Digital* (Norway, develops software for CCS technology), *CO2offset Ltd.* (Portugal, develops carbon measuring technology).

enhancing carbonate fuel cell technology to capture CO_2 from industrial facilities. *LanzaTech* (US-based carbon refining company that converts carbon into chemicals) and *Climateworks* (Switzerland-based developer of carbon removal technology for DAC) follow in employment size, each employing over 300 workers. These two companies are among the top two in terms of raising the highest capital in the sample (Fig. 8). *Climateworks*, as the only CCUS supplier in Switzerland within our sample, has the highest web growth rate (1.25%) as well as the highest capital raised ($786 million).

3.2. Identification of demand forces

Data on demand forces from CCUS facilities is obtained from the Global CCS Institute [14]. As of 2022, there are a total of 340 facilities that have adopted a type of CCUS technology, and these are found across 35 countries. Fig. 9 presents a word cloud based on text analysis to summarize their short facility descriptions. The word cloud provides some insights into the themes and focus areas for industries implementing CCUS solutions (CCUS adopters). The most prominent words are "CO_2", "capture," and "storage", indicating that these are the central components of CCUS adoption. The word cloud also suggests that CCUS adopters are largely from the energy, power, and oil and gas industries (e.g., EOR). The frequent use of "tonnes" and "per annum" suggests a focus on the quantification of the goal of CO_2 management. Words like "plant", "project", and "facility" emphasize the industrial setting in which CCUS technologies are adopted, likely referring to industrial plants, power stations, and dedicated projects designed to reduce emissions. These terms also suggest a project-based approach to CCUS adoption, often at individual industrial sites or facilities. Words like "injection" and "geological" suggest that CCUS adopters are primarily concerned with injecting CO_2 into underground storage sites, such as geological formations (CCS).

Among the 340 facilities, 35% (N=120) are found in the US, 15% (N=50) in the UK, and 4.5% (N=22) each in China and Canada (see Appendix for the location of the 340 facilities). Hence, the US ranks top in terms of having more CCUS suppliers, as well as the highest number of CCUS-adopting facilities. Among the 340 CCUS adopters, only 19% are operational, while about one-third are in the development and completion stages and are expected to start operations at or after 2025. This could mean that in the short run, the demand for carbon management could increase as some of the development stage facilities become fully operational. This effect may be strengthened with more enhanced policy incentives and the removal of non-financial barriers (e.g., the lengthy permitting process for storage sites) to impact CCUS technology adoption.

Table 3 shows that the rate of adoption of CCS is faster than CCU, where there are more commercial-scale CCS facilities across the globe. This suggests that the primary source of the increase in demand for

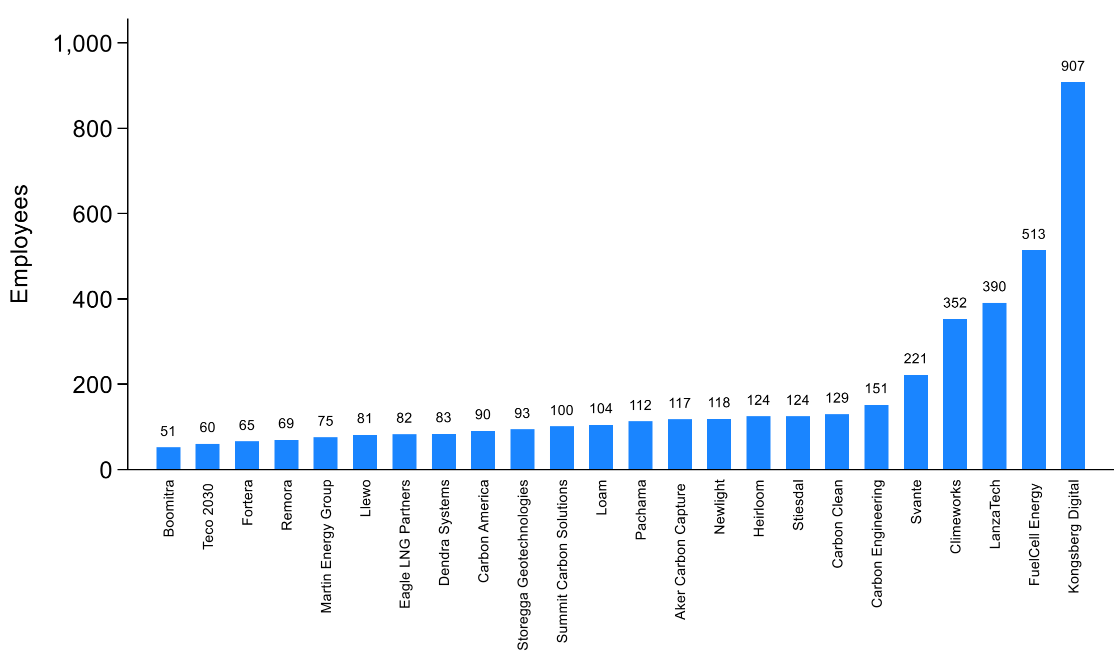

Fig. 7. Ranking of CCUS suppliers by number of employees.

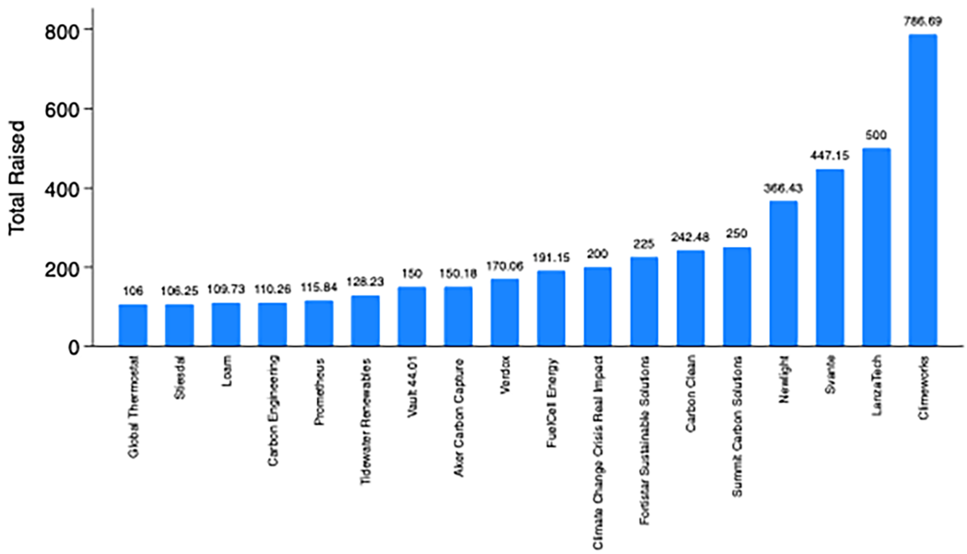

Fig. 8. Ranking of CCUS suppliers by capital raised (million dollars).

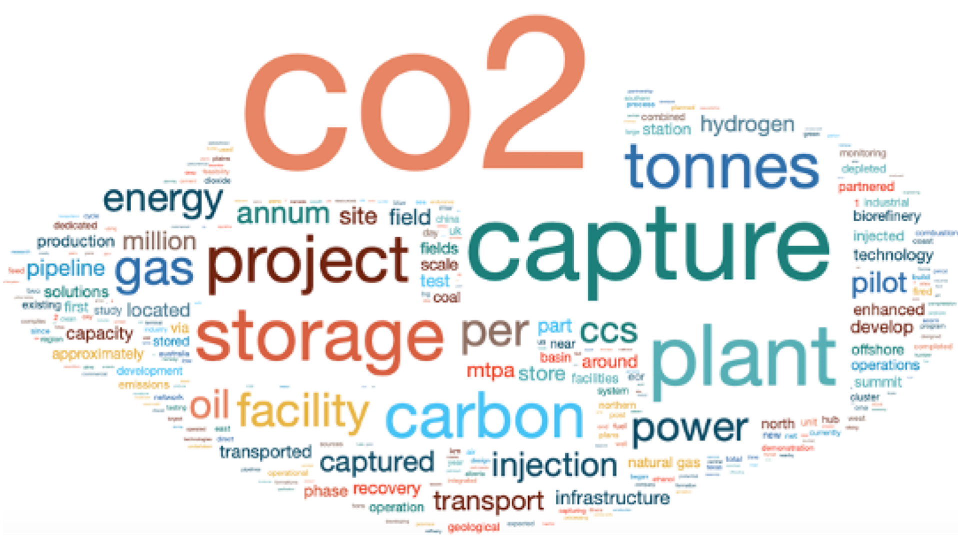

Fig. 9. Word cloud of the facility descriptions of CCUS adopters (N=340).

carbon management may be attributed to CCS rather than CCU in the short run. The top three carbon-emitting industries (about 52% of the 340 CCUS adopters) are (1) power generators, (2) ethanol producers, and (3) natural gas processing plants, a majority of which have commercial-scale CCUS.

Table 3
Status and category for CCUS adopters.

Status of CCUS adopters	Frequency	Percent
Advanced development	104	30.59
Completed	53	15.59
Early development	99	29.12
In construction	16	4.71
Operation suspended	2	0.59
Operational	66	19.41
Total	340	100
Category of CCUS adopters	**Frequency**	**Percent**
Commercial CCS	242	71.18
Pilot and demonstration CCS	97	28.53
Utilization facilities	1	0.29
Total	340	100

4. Concluding remarks

This study presents the market for carbon management capacity where CCUS technologies play a pivotal role. The analysis based on the demand-supply model emphasizes the importance of policy incentives and market-driven solutions to increase both the supply and demand for carbon management capacity. Government support through R&D subsidies, grants, and loans can encourage innovation and lower the entry barriers for new companies involved in the development and manufacturing of CCUS technologies. Additionally, a supportive regulatory framework can facilitate market-based solutions (e.g., mechanisms to raise capital and reduce risks), reduce non-financial barriers, and pave the path for more competition. Moreover, in the absence of strong market forces, a combination of incentive-based and command-and-control policies, such as carbon trading markets and taxes, may be necessary to stimulate demand for CCUS. The market analysis identifies 167 CCUS suppliers, revealing that these companies are generally smaller and raise less capital compared to other energy transition technology suppliers. Moreover, the demand side comprises 340 CCUS facilities worldwide, with significant concentrations in the US, UK, China, and Canada.

Despite the important insights gained from this study, additional studies are needed to guide future policy and investment strategies, by addressing the study's limitations. One limitation is the reliance on data from *PitchBook Inc.,* which may not capture the full spectrum of emerging or smaller players in the CCUS market, potentially overlooking significant contributors. In addition, this study identifies CCUS market players based on a text analysis of company descriptions due to the lack of a specialized industry code. Future studies can develop methods to objectively categorize and analyze companies within the CCUS sector (e. g., unique sector identification). Additionally, future studies can include certain qualitative aspects of market dynamics, such as technological advancements or regional policy variations, in addition to the use of financial metrics. Furthermore, future studies should address potential differences in the regulatory environments across countries that might affect CCUS adoption rates and financial viability. These factors could impact the generalizability of findings and warrant further investigation.

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Declaration of competing interest

Authors have nothing to declare.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sftr.2024.100374.

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