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How are oil and gas firms integrating carbon dioxide removal into their climate strategies?

William F. Lamb [a,b,*], Sean Low [c], Leo-Michael Gordon [a], Maisa Mattila [a]

[a] Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, Potsdam, Germany
[b] Priestley Centre for Climate Futures, University of Leeds, United Kingdom
[c] Wageningen University and Research, Wageningen, Netherlands

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ABSTRACT

We question whether the oil and gas sector can be relied upon to take the lead in upscaling carbon dioxide removal (CDR). Analyzing the annual reports and sustainability documents published in 2024 by the 12 oil and gas firms that are part of the Oil and Gas Climate Initiative (OGCI), we find that all firms maintain nominal net zero targets, but are vague on how they plan to scale CDR. Instead, CDR reporting is project-focused, anecdotal and combined piecemeal into an existing raft of initiatives and apparent investments into "climate solutions" consistent with the private sector turn towards environmental, social, and governance (ESG) disclosure and self-regulation. Afforestation/reforestation is the most commonly mentioned CDR approach in the guise of "nature-based solutions", often signalling linkages to developing world projects, offsets, and carbon forestry. Certain firms emphasise direct air capture and carbon storage (DACCS) and appear to seek a first-mover advantage in the context of reinforcing rather than diversifying fossil fuel extraction and production. We map this emerging integration of CDR onto the business and political strategies of oil and gas firms, and point to three possible "directions-of-travel" that firms might follow as discourse and policy on CDR develops. As it stands, we are skeptical that the sector can yet be relied upon to scale CDR, and highlight that CDR approaches may well serve as promissory technologies for the oil and gas industry to hedge against climate policy and delay decarbonization.

1. Introduction

Oil and gas firms are among the most important players in global climate governance. As internationally operating energy suppliers with multi-billion dollar investments in wells, refining and pipeline infrastructure, they face significant incentives to obstruct a phase-out of fossil fuels. Large reductions in fossil fuel extraction and combustion are, of course, a fundamental requirement for holding global temperature rise to well below 2 °C [1]. Stringent climate policy is a matter of existential concern for the oil and gas sector, with potentially trillions of dollars of foregone revenue and "stranded assets" at play [2,3]. Yet, at the same time, a dozen oil and gas firms have joined the Oil and Gas Climate Initiative (OGCI), a political organisation that declares support for the goals of the Paris Agreement and the need to transition to a "net zero economy" [4].

The notion that oil and gas firms are actively participating in efforts to support an energy transition has been met with a degree of scepticism. Third party reports emphasise that the firm's own climate pledges lack ambition and do not address the fundamental need to reduce fossil fuel production [5]. Indeed, the International Energy Agency (IEA) has found that these companies account for just 1 % of global clean energy investment and that they are currently a "marginal force in the world's transition to a clean energy system" [6]. As such, many have interpreted the climate rhetoric and action of oil and gas firms as one that offers mere lip service to an energy transition, while continuing to maintain the status quo of maximising fossil fuel production [7,8]. Meanwhile, a large corpus of work has shown that the industry has actively obstructed climate policy through misinformation, greenwashing, lobbying and other forms of corporate political activity [9–13].

In this article, we extend prior literature to investigate the engagement of oil and gas firms with carbon dioxide removal (CDR), a set of methods that remove carbon dioxide (CO_2) from the atmosphere and durably store it in geological reservoirs, marine sediments, living biomass, or in products [14]. CDR methods have an important but

* Corresponding author at: Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, Potsdam, Germany.
E-mail address: william.lamb@pik-potsdam.de (W.F. Lamb).

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specific role in climate change mitigation: by removing CO_2 from the atmosphere, they can reduce net emissions in the short-term, compensate for "hard to abate" emissions in the medium-term, and can enable the partial reversal of global warming in the long-term.

Discourses around CDR attract considerable controversy. In contrast to carbon capture and storage (CCS), CDR technologies could not only compensate for on-going emissions, but also past emissions. As such, many have argued that interest groups exploit promises of CDR deployment in the future to deter or delay strong action and emissions reductions in the present [15–17]. In this context it should be clearly stated that CDR cannot substitute for the rapid, near-term emissions reductions that underpin all pathways to reach the temperature goal of the Paris Agreement [18]. As relatively immature technologies that depend on energy, land and other resources, future CDR deployment will face multiple scale-up constraints [19]. Nonetheless, studies suggest that reaching this temperature goal will still require multiple gigatons of CDR in the second half of the 21st century [19]. This is an unfortunate consequence of decades of inaction and insufficient action on climate change - a story in which the fossil industry played a major role - thereby allowing greenhouse gas emissions to grow and almost exhausting the remaining carbon budget for 1.5 °C of warming [20].

Why is CDR important for understanding the climate strategies of oil and gas firms? First, it is relevant to explore the balance of effort between emissions reductions and scaling CDR that firms are considering with respect to their net zero goals. Given that CDR remains costly and immature in comparison to emissions reductions, it would be reasonable to expect that companies planning a serious path to net zero would prioritise the former. Second, even though the oil and gas sector is a marginal force in clean energy investment, it remains unknown what role they will have in scaling CDR. Many have commented on alignment of oil and gas operations and expertise with CCS and direct air carbon capture and storage (DACCS) [21–23]. Indeed, some firms are constructing DACCS facilities and are visibly engaging in the sector. Can we expect them to deliver? And third, given that the fossil industry has a long history of shaping the public debate around climate change and action, it is important to understand how CDR technologies are enabling oil and gas firms to reframe their own contributions to reducing emissions.

The overarching research question of this article is "*How are oil and gas firms integrating carbon dioxide removal into their climate strategies?*". Following prior work, we aim to answer this through a close reading of annual financial and sustainability reports, comparing their attention to and description of climate action with respect to both CDR technologies and a wider portfolio of emissions reduction approaches. Our analysis focuses on three specific areas, answering the following questions:

(1) *How do oil and gas firms describe the contribution of CDR to reaching their net zero objectives?*
(2) *What CDR targets, investments, projects or partnerships do oil and gas firms describe in their annual reports and sustainability documentation?*
(3) *What frames and rationales are put forward when integrating CDR into oil and gas firms existing climate strategies? Is CDR altering or entrenching these strategies?*

Our study covers all 12 oil and gas firms that were members of the OGCI in 2024. These include Saudi Aramco, BP, Chevron, China National Petroleum Corporation (CNPC), Eni, Equinor, ExxonMobil, Occidental, Petrobras, Repsol, Shell and TotalEnergies. According to the OGCI [4], these companies accounted for 27 % of global oil and gas production in 2022.

We recognise the risk that studying the CDR action and rhetoric of oil and gas firms may serve to reproduce industry narratives on climate change and its solutions. We aim to avoid this outcome by taking a critical interpretive approach, recognising that the documents we study are strongly influenced by material and ideological concerns and should not be accepted without question. In other words, we expect to observe the use of rhetoric and quantitative data to deliver value-laden stories that define particular problems, attribute responsibility and showcase specific solutions. While we approach the analysis from a neutral position vis-a-vis whether these oil and gas actors intend to engage in CDR, we aim to set this in the context of their past failures to engage in climate action, as well as ongoing efforts within the sector to undermine climate policy and regulation.

2. Literature review

2.1. What are the political and economic contexts and incentives faced by oil and gas firms?

Oil and gas firms face a number of contemporary contexts that condition their engagement with CDR, as well as their increasing adoption of net zero commitments. Over the past decade, political and societal discourse has forced these firms to pivot from outright climate denialism [24] towards acknowledging that their operations face physical climate threats, growing regulatory pressures, and litigatory and divestment threats from civil society and investors [25]. These contexts intersect with shifts towards private sector self-regulation based on risk assessment and disclosure initiatives. For oil and gas firms, this includes reporting on corporate social responsibility or CSR [26] and environment, social, and governance (ESG) criteria [27] as investor-facing concepts, and Sustainable Development Goals [28] as transnational governance principles.

In the Paris Agreement's bottom-up climate governance structure, signalling ambition through pledges has become the underlying logic of the climate regime [29]. The 2 °C and 1.5 °C targets are underpinned by a range of IPCC mitigation pathways that dramatically reduce emissions then balance the remaining "residual" carbon emissions against carbon captured by sinks in the second half of the 21st century. The resulting concept of "net zero" has come into broad usage in both state and non-governmental / private sector pledges [30,31], with commitments escalating among a broad range of sectors [32].

However, it is crucial to note that rhetorical signalling of net zero pledges currently seems to take precedence over verifiable strategic practices and quantifiable reductions in emissions. This is the case, for example, in high-carbon global corporations [33]. Industry actors - including oil and gas firms - are engaging with emissions pathways used in IPCC reports to inform their targets and plans; for example, in their reporting they deploy emissions pathways selectively, using scenarios that rely on CDR and maintain global energy growth [34–36]. Moreover, it is clear that oil and gas firms have continued to expand production despite acknowledging climate and sustainability goals, as well as norms of transparency and disclosure [5].

Economic incentives play a central role in escalating extraction. The IEA projects global demand for oil to continue increasing at least until 2030 amid strong market growth in Asia and a shift to petrochemical feedstocks that together outpace the steady decline of demand in OECD countries [37]. Further, concern over stranded assets and energy security in the context of the pandemic and the Russian invasion of the Ukraine have driven production incentives [38,39], with many supermajors delivering record profits in recent years. Oil and gas firms have shown indications of (limited) investments and projects into technologies catering to climate concerns but are not resiliently diversifying their core infrastructure, expertises, and business models [6,40].

Numerous studies show that oil and gas firms return to their core competencies around fossil fuel extraction and production when faced with uncertainties over revenues from diversification, or the strength of governmental or public pressure. Vormedal et al. [41] argue that oil and gas firms' support for carbon pricing resulted from the emergence of natural gas as a competitive replacement for coal - situating the sector's support for both carbon pricing and "bridging fuels" within the context of a "grey transition" that fit economic interests first and foremost.

Another clear example is emerging in the case of investments into renewables - whose share of operations has remained marginal or were deliberately wound down over past years despite increasingly competitive costs and growing public demand [25,42]. A mix of other technologies maintain a similarly limited presence: low carbon transport fuels (biofuels, hydrogen) and more recently electric vehicle (EV) charging infrastructure [43]. CCS has been noted for decades for its synergies with oil and gas production models, but has yet to be successfully upscaled [43,44].

This paper investigates how CDR will fit into these contexts and incentives. Prior work has shown that national Paris Agreement pledges and long-term plans already over-rely on "conventional" CDR, or ecosystems-based CDR such as land-use and afforestation/reforestation [45,46], and that industry actors, including oil and gas firms, rely on IPCC emissions pathways that include CDR to underpin their net zero commitments [35]. However, it is not known how CDR based on land and forestry management are being framed and concretely incorporated into the planning and investments of oil and gas firms as part of their climate and sustainability strategies. Meanwhile, net zero rhetoric and commitments from heavy-emitting industries - including oil and gas - in the EU highlight more nascent technology options such as bioenergy CCS, e-fuels, and 'clean' hydrogen [47]. It is similarly unclear how oil and gas firms are beginning to incorporate these "novel" CDR options based on engineered or chemical systems.

Despite coordinating on a range of climate issues through membership in the OGCI, oil and gas firms themselves face different pressures and incentives depending on the countries they operate in, the regulatory and legal threats they face, and the extent of shareholder activism they attract. They also have varying asset portfolios, value chains, and competencies. One further split is between nationally owned firms, defined as those where states hold a "golden share" or majority ownership (in the OGCI these include: Saudi Aramco, Equinor, Petrobras, CNPC and Eni) versus investor-owned "majors" (BP, Shell, ExxonMobil, Chevron, TotalEnergies, Occidental and Repsol), each of which may face different market-based logics [48]. We therefore expect to see differing levels and types of CDR integration, reflecting alternative political and business strategies to hedge against decarbonisation [25,49].

2.2. How are oil and gas firms framing their decarbonization and CDR efforts?

Oil and gas firms have come under increasing scrutiny from non-government organisations, regulatory bodies as well as the scientific community. There is therefore a growing body of research on their communication efforts and framing strategies, including work that situates these within the emerging political and economic context.

One strand of research has focused on the evolution of oil and gas firms communications with respect to basic questions of climate science. For instance, it has been shown that ExxonMobil and its precursor entities internally acknowledged and planned for the threat of climate change, while externally downplaying the credibility of climate science and its findings [13]. These communication efforts dovetailed with broader programs to propagate climate denial and undermine political responses to climate change, often through third party organisations such as industry associations, lobbying firms and PR agencies [9–12]. These practices follow a standard playbook for propagating disinformation and countering regulatory threats, as was first developed for the tobacco industry, and is now spreading to other domains of public policy [12,50].

Recent efforts have turned towards evaluating discourses as they shift away from the outright denial of climate change and its causes, towards rhetoric undermining political and social responses to climate change [16,51,52]. For example, ExxonMobil's advertorials have framed climate change as a "risk" rather than a reality, emphasised the role of the oil and gas sector in reducing emissions, and downplayed the reliability of renewable energy [53]. Other studies have identified framing attempts that link oil and gas products to human needs and everyday life [54,55]; that promote the "clean" and "transitional" role of natural gas or other fuels and technological innovations [56,57]; that highlight the importance of the industry for meeting present and future energy demands [56]; and that advertise industry efforts to counter climate damages while skirting direct culpability for climate harms [56]. The widespread use of unverified claims, distractions, irrelevancies and omissions in these examples creates deep confusion as to whether the oil and gas industry is actually a responsible player on climate change [58,59].

Still, with the development of ESG criteria and corporate net-zero targets, observers have been able to start verifying whether the climate rhetoric of firms matches up with their actions. Generally, it has been shown in the oil and gas sector that investments in renewables and clean energy technologies do not live up to pledges and rhetoric [8,60,61], nor is there evidence that firm-level incentives are sufficient to encourage them to decarbonise without external (political) pressure [62]. This has led to the conclusion that oil and gas firms remain engaged in greenwashing efforts as part of a broader resistance and hedging against climate policy and action [25,63,64].

How does CDR fit within this picture? CDR is defined as human activities that extract CO_2 from the atmosphere and store it durably in ecosystems, geological reservoirs or products [65]. There are two relatively distinct sets of CDR technologies: (1) conventional CDR, which comprises interventions largely in the land use sector (e.g. afforestation, reforestation or forest management practices), as well as other adjacent options such as wetland restoration; and (2) novel CDR, which involves technologies at a low state of readiness, including DACCS, BECCS, biochar, enhanced weathering and others. Discussions around the communication of CDR have often focused on a nature/technology dichotomy, which relates - albeit not perfectly - to these categories [65]. Together, these options have the common feature that they should result in net removals from the atmosphere - in contrast to fossil-based CCS, which at best can only result in zero net emissions from individual point sources.

The entry of CDR into the climate discourse has major repercussions for policy and private actors. Carton et al. [66] have argued that the accounting logics implicit in CDR discourses have created false equivalences between different types of emissions and removals (e.g. fossil, land use and ecosystem based carbon) and their geographic and temporal characteristics. In other words, these technologies enable actors to justify the substitution of local mitigation action in the present, for action elsewhere or in the future. The resulting concern of "mitigation deterrence" or "kicking the can down the road" has been widely discussed in the literature, and has generated significant reflection on the extent to CDR could indeed fulfil a major role in climate mitigation under different assumptions of technology scale-up with varying sustainability constraints on land and energy resources [19,67,68].

To our knowledge, this is the first study on how oil and gas firms frame CDR in their decarbonisation efforts. Or, put another way, it is the first to investigate how CDR feeds into their efforts to hedge against decarbonisation [17]. CCS, of course, has been a major focus of climate communication studies and one that offers a clear analogue to certain CDR technologies. Nonetheless, few have actually explored how oil and gas firms shape their rhetoric around CCS. In a study of fossil fuel industry documents, including Chevron, ExxonMobil, BP, and Shell, Gunderson et al. [69] identify three core frames: (1) *faith in innovation*, or optimism that the technical and economic barriers that have plagued CCS projects to date will be overcome; (2) *value instrumentalisation*, or the justification of new technology developments as inherently good; and (3) *status quo maintenance*, or rhetoric that celebrates CCS as a technology that can preserve the fossil extraction system. Similarly, Beqja [70] examines CCS industry frames in Europe, finding elements of technological optimism and efforts to legitimise the fossil industry. Braunreiter and Bennett [71] find that in external communications, oil

and gas firms hype CCS while putting the onus for CCS upscaling on governmental support. In internal processes, these same firms see CCS as unprofitable and engage in limited investment in order to hedge towards future market expansion.

But, as stated above, CDR is different from CCS in several important respects. It offers a broader scope for equivalising current fossil emissions and distant or future mitigation efforts. It also provides an entry point for promoting "nature based solutions" that are well-regarded among publics globally [72–74], alongside frames that emphasise innovation and technological progress. It is therefore critical to understand how these features of CDR can be exploited by interest groups to greenwash status quo operations, disguise minimal efforts, and avoid deeper commitments to diversification [64,75].

3. Material and methods

Our primary data source is a compilation of annual reports and sustainability documents published by the 12 selected OGCI oil and gas firms. All annual reports (ARs) were downloaded in the first to second quarter of 2024, and refer to the 2023 financial year. In addition to these documents, we read a set of sustainability reports (SRs) published by 9 of the firms (BP, Chevron, CNPC, ENI, Exxon, Occidental, Petrobras, Shell and Total) which provide more detail on their respective climate strategies. Most of these were also companion reports for the 2023 financial year, apart from ENI and Petrobras (published with the 2022 financial year reports), and Exxon and Total (published in 2024 and not referring to prior financial years).

3.1. Study design

Our general approach is first of all based on a qualitative coding of the oil and gas firms' documents. We drew from the scientific and grey literature to evaluate three main categories of information and disclosure in each document:

(1) **Overall climate strategy.** We assess whether or not each firm has elaborated a target or pledge to reach net-zero; whether this target is more specified in terms of scope (e.g. gases, sectors); and whether there is a planned division of effort between reductions and removals.
(2) **Overall CDR strategy.** We assess whether or not each firm has described its overall objectives to scale CDR, including defining these activities and presenting removal targets or investments. We also judge which individual technology appears to be the main focus of a major's description of CDR efforts, if any.
(3) **Specific mitigation strategies.** For each CDR or emission reduction technology that is mentioned by a firms, we record any description of targets (e.g. CO_2/year removed, capacity levels, or % reduction targets), investments (e.g. $USD), flagship projects, or partnerships (e.g. private sector, governments).

When coding specific mitigation strategies, we use a predefined list of technologies and mitigation approaches (Table 1). This includes a list of CDR methods, which cover both novel approaches such as bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS), as well as conventional CDR approaches such as afforestation/reforestation or blue carbon. While the former approaches might be expected to be more relevant to oil and gas firms, we code for a wide range of CDR methods in order not to preclude those which are actually mentioned by them.

As we are interested in how oil and gas firms are developing CDR in comparison to a broader portfolio of mitigation efforts, we also code for a range of non-CDR mitigation strategies. The list of these strategies is guided by prior work exploring oil and gas investments in renewable energy deployment [8], as well as a list of "technology options for the oil and gas industry" developed by the International Energy Agency in their assessment of how this sector can contribute to net zero transitions [6]. They cover operational emissions reductions and industrial decarbonisation; renewable energy deployments; and several other options that do not fall in the above categories. Indeed, some of these other options are not necessarily climate mitigation strategies but are associated with broader sustainability objectives (plastic recycling), are perceived as similar but are conceptually distinct from CDR (forestry offsets), or are options that exploit CDR processes to increase fossil fuel production (enhanced oil recovery). As we discuss below, it should be noted that several of the listed technologies are derivatives of one another or overlap in terms of research, implementation and deployment.

Table 1
Assessed CDR and emission reduction technologies.

Category	Technologies and mitigation strategies
Carbon dioxide removal	Afforestation/reforestation
	Biochar
	Bioenergy with carbon capture and storage (BECCS)
	Direct air carbon capture and storage (DACCS)
	Direct ocean carbon capture and storage
	Enhanced rock weathering
	Peatland/coastal wetland restoration
	Soil carbon sequestration
	Ocean alkalinity enhancement
Emissions reductions and industrial decarbonisation	Energy efficiency
	Methane/flaring reductions
	Fossil-based carbon capture and storage (CCS)
	Hydrogen/ammonia production
	Bio/synthetic fuel production
	Electric vehicle (EV) charging
Renewable energy	Generic renewables
	Solar power
	Wind power
	Geothermal power
Other	Forestry offsets
	Enhanced oil recovery (EOR)
	Plastic recycling

The overall objective of our coding scheme is to structure the analysis of the oil and gas firms' reports and improve comparability between them, as they tend to be rather diverse with respect to content and format. Further, it allows us to more explicitly consider which information is disclosed by majors, and what types of information are omitted. The practice of coding company reports is well established in the literature, and this exercise here can contribute to a more structured tracking of oil and gas major activity in the domain of CDR going forward.

In addition to coding the inclusion and exclusion of selected information within documents, we conduct a qualitative analysis of the frames and rationales implicit in oil and gas firms' communications. Specifically, we focus on projects as a prevalent mode of documentation and signalling. These project descriptions are significant for being anecdotal, with selective detail intended to advertise key processes, purposes, and the added value of developing CDR approaches. These include: collaborations with other oil majors; collaborations with civic, innovation and industry, and policy actors at home (the headquartering state) and abroad; adherence to regional or international frameworks; showcasing or qualifying explorative innovation; highlighting particular approaches to signal intent or action; highlighting types of CDR which are complementary to company objectives or competencies; and highlighting wider commercial, developmental, and research co-benefits. There are parallels with how other projects in renewables, climate action, ESG criteria are talked about elsewhere - qualitatively and with limited comparability in terms of emissions reduced or benefits achieved.

4. Results

4.1. How do oil and gas firms describe the contribution of CDR to reaching their net zero objectives?

As of 2024, all oil and gas firms in the OGCI initiative have plans to become "net zero" companies (Fig. 1). Therefore, at least implicitly they acknowledge the need to both reduce emissions and scale up CDR. A common objective is to reach net zero greenhouse gas emissions by 2050, much like the pledges put forward by countries and firms in other sectors [76]. Some firms do specify net zero "carbon emissions" or "carbon neutrality" (CNPC, ENI), which is generally a weaker formulation, as it excludes non-CO_2 emissions, of which CH_4 from venting and well or pipeline leaks is a major contributor to warming from the sector.

All oil and gas firms apart from CNPC specify which emissions associated with their businesses would be covered by their net zero plans. This is important, as just like target years and the coverage of gases, it provides a benchmark of ambition. Most firms describing the scope of their targets aim to neutralise the emissions directly produced by each firm ("scope 1 emissions"), as well as the emissions that they indirectly accrue by purchasing electricity or heat from the power sector ("scope 2 emissions").

A smaller subset of firms mention "scope 3 emissions", or the emissions associated with the combustion or use of their products by consumers. Occidental Petroleum, ENI and Repsol set goals to reach net zero GHG emissions for Scope 1, 2 and 3 by 2050. In other words, they aim to take responsibility for, and to neutralise the emissions associated with, the use of their oil and gas products by consumers. Equinor, Shell and BP also refer to Scope 3 emissions; however, in terms of carbon intensity reductions than a net zero target.

Despite the relatively high level of transparency in overarching net zero targets, oil and gas firms are more vague when it comes to the specific detail (Fig. 1). Concretely, most do not provide targets for scaling CDR technologies, neither in the short nor the long-term, with the exception of Occidental Petroleum, which highlights an interim target to "facilitate" 25 $MtCO_2$/year of removals by 2032. Conversely, firms also fail to provide gross emissions reductions targets, which could be used to infer a contribution from CDR. Instead, there is a tendency to formulate emissions reductions plans using net accounting conventions. For example, Aramco aims to abate "52 MMtCO2e" per year by 2035 through a combination of technology measures and "…including the use of natural climate solutions, and using offsets to address hard to abate emissions in our operations" (Aramco SR 2023 p30). Similarly, other firms state objectives such as a "net 50% emission reduction by 2030 compared to 2015 levels" (Equinor AR 2023 p103) or a "net carbon intensity reduction" of 100 % by 2050 (Shell AR 2024 p8).

In general, oil and gas firms tend to group emissions reductions and CDR under broader categories of "low carbon energies", "energy solutions" or "climate solutions". CDR is therefore nested within wider strategies confronting demands for climate, sustainability, and environmental, social, and governance (ESG) criteria in investment and corporate governance, and is not typically emphasised as a distinct category of action.

This is reflected in their disclosed investment activity, which is often centred on specific "funds" or corporate sub-divisions that group together an aggregate mix of upstream and downstream activities, including renewable power production, CCS, hydrogen and synthetic fuels, and EV charging (Table 2). The annual reports do not tend to break down these investments into specific categories, and usually they are spread over a longer forward looking time horizon. It is also largely unclear how these investments compare to core expenditure on oil and gas infrastructure, although a handful of firms do set investment targets for these overarching categories (e.g. Equinor aims for 30 % of capital expenditure on "low-carbon solutions" by 2025; Repsol proposes to spend 35 % of investments up to 2030 on "low-carbon initiatives"), although not for CDR specifically. Aramco's fund stands out as particularly small compared to both its net income in a single year and those of other companies, while BP and Repsol's funds are rather more ambitious in relative expenditure (Table 2).

A consequence of this aggregation of "climate solution" activities is that it is currently impossible to assess the ambition of firms in terms of scaling CDR, at least directly. A further consequence is that it is generally difficult for observers to disentangle the more promising investments in terms of emissions reductions, compared to those that

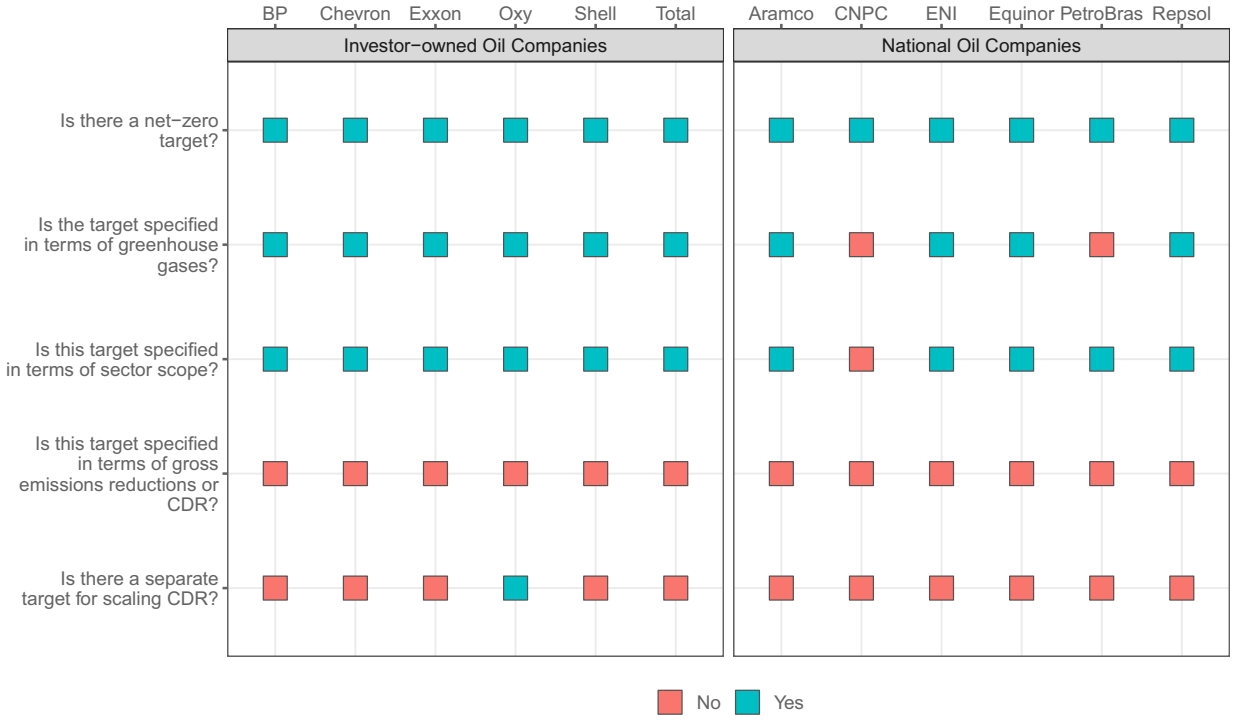

Fig. 1. Disclosed net-zero, emission reduction and CDR targets of 12 oil and gas firms.

Table 2
Cross-cutting investments in climate mitigation, emissions reductions and CDR technologies of selected oil and gas firms. Information not found for CNPC, ENI, Equinor, Oxy and Total. Net income values are reported for 2023 after tax.

Oil & gas major	Net income ($b)	Fund name or investment category	Total value ($b)	Time horizon	Areas of focus
Aramco	121	Sustainability Fund	1.5	None given	CCUS, energy efficiency, nature-based solutions, digital sustainability, hydrogen, ammonia, synthetic fuels
BP	15.4	Transition Growth Investment	46–64	2022–2030: 3–5 per year (2022–2024), 6–8 per year (2025–2029), 7–9 per year (2030-)	EV Charging, renewables, hydrogen, biogas
Chevron	21.4	N/A	10	2023–2028	Renewable fuels, hydrogen and carbon capture and offsets ($8b), reducing oil and gas operations carbon intensity ($2b)
Exxon	36	Low Carbon Solutions	17	2021–2027	Carbon capture and storage, hydrogen, lower-emission fuels, lithium
PetroBras	25	Decarbonization Fund	11.5	2024–2028	Biorefining, wind, solar, CCUS, hydrogen
Repsol	3.2	N/A	5.6–6.65	2024–2027	Low emissions electricity generation, renewables, renewable fuels, hydrogen
Shell	19.6	N/A	5.6	None given	E-Mobility and electric vehicle charging services, low-carbon fuels, renewable power generation, "environmental solutions", hydrogen, CCS

could be argued to sustain the status quo. For example, Total's taxonomy of "low carbon energies" includes electricity, the distribution of biofuels, sales of biomass, biogas and H2. Yet electricity production itself appears to include generation from conventional gas plants (Total SR 2024 p99). Similarly, BP defines low carbon activity in its glossary (BP SR 2023 p60) as including blue hydrogen production. Both of these are greenhouse gas emitting activities. However, they are presumably included on the basis that they are relatively lower carbon operations compared to oil and gas extraction.

4.2. What CDR targets, investments, projects or partnerships do oil and gas firms describe in their annual reports and sustainability documentation?

In the absence of overarching CDR targets, what detail do oil and gas firms give on specific options? Again, we find scant attention to CDR options and technologies. Nevertheless, some exceptions are illustrative (Fig. 2). For each technology, we coded 5 basic categories: mentions, targets, investments, partners, and projects. While these categories are not equivalent in terms of "weight", we interpret more of them being present for a given climate strategy as a signal of greater intent to engage in them. Even on the most basic of these criteria - mentions - we find that the majority of CDR options are either referred to not at all, or are only referred to by one or two of the oil and gas firms. Not a single oil and gas firm mentions BECCS, biochar, enhanced rock weathering or ocean alkalinity enhancement. Of these, the absence of BECCS is most notable, given its prominence in the climate mitigation and scenario literature. Exceptions are afforestation/reforestation (mentioned by 9 firms), DACCS [5], and peatland/coastal wetland restoration [5].

Afforestation/reforestation is by far the most prevalent of the CDR technologies mentioned (Fig. 2). These tend to have a strong focus on projects that highlight conservation/restoration or tree-planting campaigns. Typical project descriptions include statistics on how many hectares were restored, or how many millions of trees were planted. Often they are selective, anecdotal, and do not reference carbon accounting figures: "Aramco has planted 24 million mangroves along the Arabian Gulf and Red Sea coastlines and over 3 million terrestrial native trees - and we plan to plant millions more" (Aramco SR 2023 p38). Some firms take a forward looking perspective and describe carbon removal targets associated with these kinds of activities (e.g. Chevron, ENI). However, their targets are impossible to distinguish from avoided emissions offsets, thus blurring the boundaries between different categories of mitigation effort and preventing observers from assessing which afforestation/reforestation projects are additional and lead to net removals.

Occidental Petroleum stands out for its relatively in-depth elaboration of a novel CDR method: DACCS. It describes its acquisition of the DACCS company Carbon Engineering, its partnership with the BlackRock investment fund to develop the STRATOS plant in Texas, and the targeted removal capacity of this plant of 0.5 MtCO2/year. Aramco's mention of DACCS is more cursory, while ExxonMobil and Repsol reference a recent pilot plant and startup investments in DACCS, respectively.

The lack of attention by firms on CDR technologies and solutions strongly contrasts to the broader landscape of mitigation options, where discourses are much more developed. Among these other options, fossil-based CCS, hydrogen production, methane flaring and generic renewable energy deployments tend to be the most mentioned. More concrete discussions of projects, partners, investments and targets are also more prevalent in these categories.

4.3. What frames and rationales are put forward when integrating CDR into oil and gas firms' existing climate strategies? Is CDR altering or entrenching these strategies?

In previous sections, we noted that oil and gas firms generally group emissions reductions and CDR under broader categories of "low carbon energies", "energy solutions" or "climate solutions" (4.1), while also emphasising certain CDR approaches through targets, investments, and flagship projects (4.2). In this section we bring more detail to these overviews, qualitatively examining the frames and rationales underpinning CDR, analyzing how different CDR approaches and projects are described and emphasised by different firms, and evaluating how they underpin different courses of action (Table 3).

4.3.1. Ecosystems-based CDR appeals to naturalness, co-benefits, and local collaboration

"Nature-based" or "nature-based solutions (NbS)" is a ubiquitous formulation of ecosystems-based approaches such as afforestation/reforestation and peatland/coastal wetland restoration. NbS in turn is linked to a further complex of terminology and stated intents. The most common link made by oil and gas firms is to engage in these projects with the intent to support biodiversity and ecosystems services, delivering benefits for local development while collaborating with local companies or NGOs (8 firms), both in states where the firm is (nominally) headquartered or in other countries, typically developing states. BP and Petrobras note that their projects cater towards the restoration of native species; other firms do not specify. Chevron alone refers to a soil carbon sequestration project and takes care to earmark "holistic management and regenerative farming practices" (Chevron SR 2023 p47).

Within these types of projects, further emphases are given: the potential to generate new credits in voluntary markets, the use of offsetting

Fig. 2. Disclosed carbon dioxide removal, climate mitigation and other technology activities of the 12 oil and gas firms.

for oil and gas purchases by consumers and the development of ongoing carbon forestry projects. Firms highlight the quality of the particular monitoring, reporting and verification (MRV) process that they subscribe to (Chevron, CNPC, Eni, Petrobras, Shell), while also advertising adherence to international entities and mechanisms such as REDD+ (Chevron, Eni, Petrobras), as well as the United Nations Framework Convention on Climate Change or the Sustainable Development Goals (Eni).

4.3.2. CCS is highly promoted, with emerging and latent connections to support for DACCS

References to investments and projects in CCS and sourcing new storage locations are common for all firms (all 12 firms mention CCS, and 11 describe projects, see also Section 4.2). Occidental Petroleum, ExxonMobil and Chevron explicitly link CCS and/or storage to intent for DACCS development - Occidental most of all. The other firms do not, even though there is an obvious latent connection between CCS and DACCS systems through the development of carbon transportation and storage infrastructure.

More common are framings of CCS as a means to prolong oil and gas production, and/or to mitigate emissions in a "hard-to-abate" sector (6 firms). There are several technological complexes cited: CCS and enhanced oil recovery or EOR (5 firms), stressing operational efficiency and extension of the life of existing oil fields (4 firms), capturing emissions from liquified natural gas (LNG) through CCS (6 firms), and creation of blue hydrogen from LNG and CCS (4 firms). To highlight the

Table 3
Frames and rationales underpinning the integration of CDR into oil and gas firms' climate strategies.

Theme	Oil and gas firms	Representative quotation
Section 4.3.1: Nature-based solutions linked to biodiversity, co-benefits, and local collaboration.	Aramco, BP, Eni, ExxonMobil, Petrobras, Repsol, Shell, TotalEnergies	"…ecological, social, and economic co-benefits, including natural climate solutions that reduce or remove greenhouse gas emissions through nature conservation, restoration or improved land management." (BP SR 2023 p48)
Section 4.3.1: Carbon forestry credits and high quality accounting	Chevron, CNPC, Eni, Petrobras, Shell	"In 2020, we intended to progress nature-based solutions verified by recognized carbon credit standards. Carbon credits generated by high-quality nature-based projects may be used to offset emissions in line with the mitigation hierarchy of avoid, reduce and offset…" (Shell AR 2023 p193)
Section 4.3.2: Explicitly linking CCS and/or storage to intent for DACCS development	Occidental, ExxonMobil, Chevron	"Occidental believes that carbon removal technologies, including DAC and CCUS, can, with incentives necessary for their development and deployment, provide essential CO2 reductions to assist the world's transition to a less carbon-intensive economy; DAC: Direct Air Capture." (Occidental SR 2023 p91)
Section 4.3.2: CCS to prolong oil and gas production, and/or to mitigate emissions in a "hard-to-abate" sector	Aramco, Chevron, Eni, Equinor, Repsol, Shell	"Repsol's energy transition strategy also envisages CCS (CO2 capture and storage) projects. These projects will contribute to reducing the Company's operational emissions in specific projects, and provide medium- and long-term solutions for sectors with hard-to abate emissions." (Repsol AR 2023 p68)
Section 4.3.2: CCS and EOR	BP, CNPC, Occidental, Petrobras	"… extraction of carbon dioxide from produced gas streams and reinjection underground can serve to reduce overall operational emissions. We believe this could be the case at our Tangguh LNG facility in Indonesia, where we are continuing work on the Tangguh Enhanced Gas Recovery and CCS scheme" (BP SR 2023 p20)
Section 4.3.2: LNG and CCS	Aramco, BP, Equinor, Repsol, Shell, TotalEnergies	"…the native CO2 separated in the new NFE and NFS LNG liquefaction trains currently under development will be stored by QatarEnergy. The same will be true for the native CO2 separated on Cameron LNG to be stored in the Hackberry CCS storage facility in the context of a new train project by Cameron LNG…" (TotalEnergies SR 2023 p38)
Section 4.3.2: LNG and CCS for blue hydrogen	Aramco, BP, Equinor, Shell	"Providing hydrogen by reforming natural gas with CCS: Hydrogen provides a solution to hard to abate emissions from industries. Equinor is involved in projects aimed at producing low-carbon hydrogen from natural gas with CCS…" (Equinor AR 2023 p141)
Section 4.3.2: Regional infrastructure or value chains for CCS	Aramco, Eni	"Callisto: creation of a CCS value chain in Southern Europe and the Mediterranean basin (Ravenna and Ferrara, and from the Marseille Fos in France)…" (Eni AR 2023 p73)
Section 4.3.2: Co-location with existing storage locations	Equinor, ExxonMobil	"Equinor and its partners secured additional CCS storage licenses in the Northern Endurance Partnership, adding up to 4mtpa to our annual storage capacity in the project, which comprises six CO_2 storage sites in the southern North Sea." (Equinor AR 2023 p22, 141)
Section 4.3.3: Seeking first mover advantages regarding DACCS	Occidental, ExxonMobil	"By pairing DAC with our existing infrastructure, we aim to remove an amount of CO2 equivalent to that emitted during the production and consumption of our products. Alongside our plans to reduce our operational emissions, this can result in net-zero oil and gas" (Occidental AR 2023 p27) "ExxonMobil plans to play a lead role in accelerating the development of cost competitive and scalable DAC technology with our in-house expertise and select partners." (ExxonMobil SR 2023 p69)
Section 4.3.3: "Grey" transition focusing on oil and gas competencies	Occidental, ExxonMobil	"Occidental believes that its core competencies in CO2 separation, transportation, use, recycling and storage in EOR provide a competitive advantage over its peers as the world transitions to a less carbon-intensive economy and seeks to remove CO2 from the atmosphere" (Occidental AR 2023 p7) "We're clear-eyed on the challenges, and we understand the unique contributions we can make. Our strategy is geared towards ensuring strong returns with a focus on carbon capture and storage, hydrogen, lower-

(*continued on next page*)

Table 3 (*continued*)

Theme	Oil and gas firms	Representative quotation
		emission fuels, and lithium." (ExxonMobil SR 2023 p20)

value of their CCS projects, certain firms further emphasise the development of regional infrastructure or value chains for CCS (Eni and Aramco), or the potential of co-location with existing storage locations (Equinor in the North Sea, or ExxonMobil on the US Gulf Coast).

Interestingly, Chevron references core insights from the IPCC, whose most ambitious mitigation pathways, calculated by integrated assessment models, are driven by upscaling biomass energy CCS or BECCS. However, Chevron interprets these pathways as support for DACCS and fossil-based CCS in the face of "the continued use of oil and gas, even in rapid decarbonization scenarios" (Chevron SR 2023 p26). For now, it appears to be the only firm to use this justification.

4.3.3. Firms motivated by varying first-mover and comparative advantages, including leveraging rather than diversifying oil and gas competencies

Emphases on different CDR approaches point to interlinked sectoral and political rationales. The first is gaining a first-mover advantage by allocating attention and comparatively high investment to particular low-readiness approaches. The clearest example is the emphasis of Occidental Petroleum on DACCS to produce "net zero oil and gas" (Occidental 2023, p27) and to a lesser extent, ExxonMobil, Aramco, and Repsol. Aramco and Equinor are the only firms to highlight direct ocean capture - both working with the same innovator, Captura. Other examples highlight the benefits that might accrue from CDR systems, such as 'high-quality' carbon forestry credits (5 firms, see 4.3.1), or the co-benefits for research and innovation with the academic sector from sourcing and assessing carbon storage capacities (Aramco, ExxonMobil).

A second rationale caters to existing comparative advantages linked to national interests - for example, the co-location of primary operations with potential carbon storage sites (Equinor), or the importance of the land-use sector and its relevance for afforestation/reforestation and credits (Petrobras).

A third rationale - and from the prospect of an energy transition, most troubling - situates CDR within a "grey" transition that focuses on firms' core competencies, rather than diversifying portfolios for energy provision or climate/sustainability action. The majority of firms incorporated individual CDR approaches within unclearly-categorised collections of climate, sustainability, and ESG-facing strategies that also included renewable energies, green hydrogen, energy efficiency, EV, and others (Section 4.1). ExxonMobil and Occidental, however, especially focus on strategies surrounding oil and gas production: CCS, (blue) hydrogen, "lower-carbon" fuels, and EOR.

4.3.4. Correlation between strong support for CDR and weak support for renewables is partially present yet inconclusive

The correlation between support for different kinds of CDR and how firms describe rationales for projects and investments into renewable energies and wider climate/sustainability strategies is currently inconclusive. The reports from Repsol and TotalEnergies contain the most progressive rhetoric and most diverse baskets of projects and investments into "climate solutions". Those firms, alongside BP, Equinor, and Petrobras, frame their investments into renewables as portfolio diversification, taking care to detail flagship projects locally and in select developing countries. Others - Chevron and Occidental - cite only the more limited rationale of lowering operational emissions. Shell, Eni and Aramco are ambiguous, while ExxonMobil does not highlight renewable investments at all. The focus of Occidental and ExxonMobil on DACCS tracks with their conservative climate-facing strategies more generally; for the other firms, this remains unclear.

5. Discussion

In this article we have focused on how oil and gas firms engage with CDR activities. Our analysis covers both overarching climate targets and strategies, as well as more concrete plans, projects and investments. In doing so, we observe emerging frames and rationales for CDR, which point towards either largely symbolic gestures in the space of "natural climate solutions", or in some more specific cases an early engagement with novel methods such as DACCS that align with the core competencies of firms.

Since the integration of CDR into the climate strategies of oil and gas firms remains at an early stage, what are possible directions-of-travel in the coming years? Here we draw on Green et al. [25] to situate firms in terms of pro or anti-climate business and political strategies and suggest three possible directions that firms might take as they further integrate CDR. First, they might follow a "Transitioner" strategy in which they could commit to phasing down oil and gas production, while diversifying business strategies towards a portfolio of renewables, energy services, CDR and industrial decarbonisation, as envisaged by the IEA [6]. Second, they might follow a "Greenwasher" strategy that puts further emphasis on nature based solutions and carbon forestry, while largely maintaining the status quo in terms of core fossil production activities. Or third, they might follow a "Prepper" strategy where increased emphasis is placed on a grey transition, leveraging DACCS and CCS with intent to hedge against new markets while driving forward EOR projects. There is also the possibility that firms do not shift their strategy at all, for example by dropping any pretense to interest in either CDR or other diversification strategies in a "Resister" logic that opposes climate transitions in both the political and business sphere.

Situating firms in this space, Repsol, TotalEnergies and Eni appear to have the most progressive rhetoric around energy diversification and renewables, and most diverse combination of climate/ESG related investments, targets and projects - more so than most - possessing potential towards "Transitioning" (Direction 1 in Fig. 3). Yet, it is not clear if these efforts represent a serious direction-of-travel. They are not transparent on the fraction of overall resources CDR or broader diversification takes up; moreover, they do not refer to novel CDR methods, and only advertise engagement in afforestation/reforestation and other conventional approaches.

Where firms lack a clear commitment to diversification but nonetheless heavily promote ecosystem-based CDR, we interpret this as a tendency towards "Greenwashing" (Direction 2 in Fig. 3). Here we observe that the majority of the 12 oil and gas firms - but in particular Aramco, BP, Eni, Equinor, Shell and Petrobras - have cited projects labelled either as 'Nature-based Solutions (NbS)' or the related term 'Natural Climate Solutions'. (Both terms are highlighted in communications by the OGCI itself [77], demonstrating some degree of coordination). These firms further reference biodiversity co-benefits, ecosystems services and local development projects in the same complex of justifications, but appear to allocate trivial resources towards such efforts.

Occidental and ExxonMobil have the clearest "Prepper" framings, signalling an attempt to gain advantage over their competitors should a market emerge, while doubling down on core oil and gas competencies and around climate solutions that appear to serve continued extraction (Direction 3 in Fig. 3). They give much less (even rhetorical) support to renewables or diversification, and only refer to DACCS as CDR methods. Further, their adoption of the term "net zero oil and gas" reflects a longer history of framings that emphasise "lower carbon" or "clean" fuels and operations.

While most firms sit between these political and business positions, we argue that a specific focus on CDR reveals important insights on their potential directions-of-travel. CDR options and technologies are nascent and face significant scale-up challenges, and are generally longer-term prospects compared to other mitigation options available to oil and gas firms such as methane capture. Whether or not engagement with

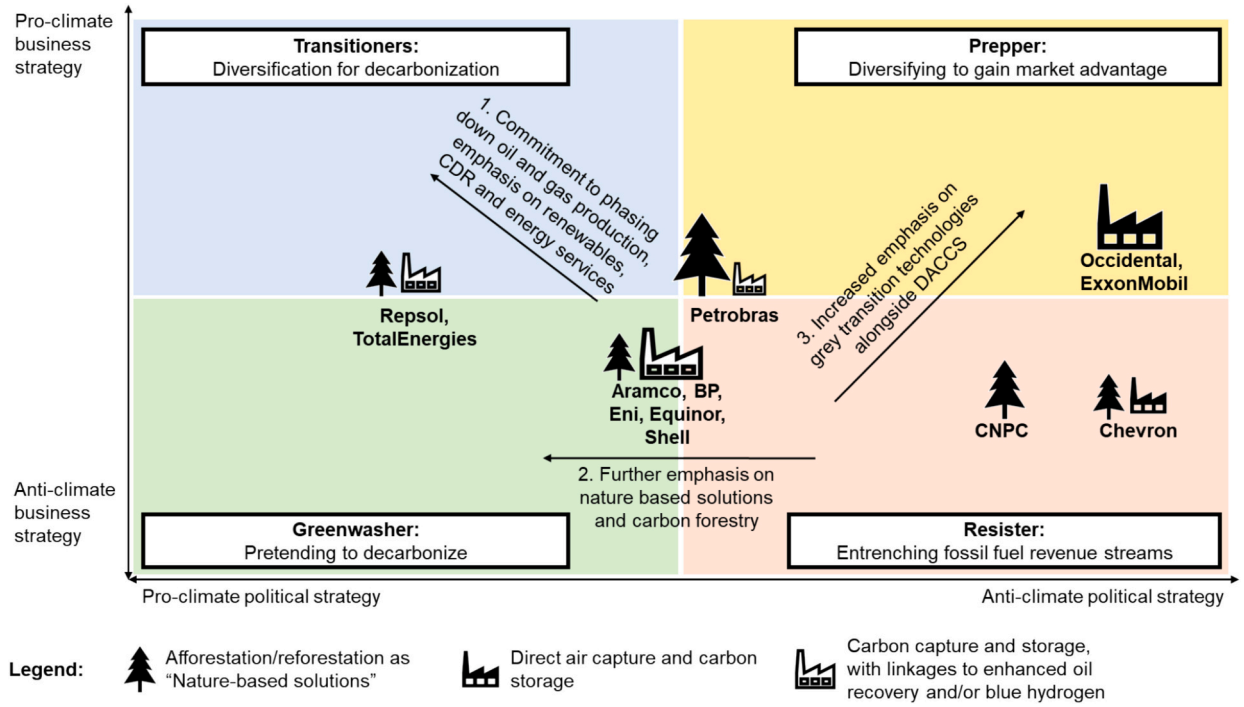

Fig. 3. Carbon dioxide removal strategies of oil and gas firms. Adapted from Green et al. [25], which maps the decarbonization strategy space of oil and gas firms, where the y-axis represents firm business operations and the x-axis represents firm politics and policy strategy. We import emerging strategies for carbon dioxide removal (CDR) onto this space. The size of the icons show the relative emphasis of an oil major on ecosystems CDR versus direct air capture and carbon storage (DACCS), with carbon capture and storage (CCS) added as a potential precursor systems component. The arrows depict three potential directions-of-travel for integrating CDR approaches into oil and gas firms' climate strategies.

CDR is serious or cursory depends on tackling such challenges, which again are distinct for the different categories of "conventional" ecosystems-based CDR and "novel" chemical/engineered CDR.

With regards to conventional CDR, it is clear that oil and gas firms are piggy-backing on the emergence of NbS as a key pillar of biodiversity, climate, and environmental governance [78], including its relatively benign and well-regarded image among the public as a desirable mitigation option [72–74]. At the same time, a growing literature shows that NbS efforts have become increasingly co-opted as a rhetorical tool and a low-cost pathway to avoid undertaking emissions reductions [79,80]. Recent work has shown that the forestry offset market faces severe credibility issues, including additionality concerns, conflicts of interest among MRV providers, and broader issues of reversibility and mounting climate impacts [81–83]. While offset projects should not be strictly regarded as CDR, oil and gas firms often do not make a clear distinction between offsets and afforestation/reforestation, and many of the underlying issues will be faced by both [14]. Perhaps in reflection of this, some firms pointedly refer to 'high quality' carbon forestry credits, while generally glossing over the larger difficulties in this area.

It should also be noted that engaging in NbS schemes or even afforestation/reforestation projects can in no way compensate for the environmental harms wrought by oil and gas production and use. This is clear from both the scale of the projects that are put forward and the fact that forestry based CDR is impermanent and has limited equivalence to fossil fuel emissions. Even one of the most ambitious cases - Saudi Aramco's mangrove restoration strategy which expects to "remove and offset an estimated 16 MMtCO2e by 2035" - is trivial compared to its projected scope 1 to 3 emissions in the same time period [84]. Together, the lack of self-reflection on these issues in oil and gas firm reporting lends further credibility to the interpretation of a "Greenwashing" direction-of-travel.

With regards to novel CDR, analysts have noted, with good intent, that the expertises, infrastructures, and so-called stranded assets of the oil and gas industry can be pragmatically leveraged for upscaling novel CDR options such as DACCS [21–23]. However, lessons from the history of CCS development should be illustrative. For almost two decades, analysts have been hopeful - even bullish - that oil and gas firms could play a role in upscaling CCS. The synergies between fossil fuel extraction and CCS in both infrastructure and climate strategy were recognized early on with the publication of the IPCC Special Report on CCS [85], in which the industry was named as a key sector, around which time certain firms began to invest in R&D projects [86].

Yet, it is clear that even now, the role of CCS in oil and gas climate strategies remains at the level of individual projects and is marginal to their overall operations [44]. Studies note that high costs, uncertainty over policy and societal opposition [87,88] have not helped CCS uptake. Despite this, oil and gas firms have publically hyped the potential of CCS as a climate strategy, and in doing so have accessed and influenced policy conversations and pre-empted investor or public concerns over climate change [71]. At the same time they have minimized their own role in scaling CCS by framing it as an "incremental innovation" reliant on improvements in governmental support, while undertaking a limited range of CCS projects mainly to gain an early advantage should the market (unexpectedly) expand [71].

Given this context, it is surprising to observe the position put forward by some firms that the full life-cycle emissions of their products can be neutralised through CDR (ENI, Repsol), and more specifically that it can be done via DACCS (Occidental). Compared to the concentrated streams of CO_2 that CCS facilities would be attached to, DACCS must extract CO_2 from ambient air and thereby faces substantially greater thermodynamic penalties and thus energy costs. And even though the sector is attracting significant investment, current deployment costs remain very high [14]. Technology analogue studies emphasise that even in the best case, with a concerted global policy push equivalent to that which scaled-up ammonia synthesis in the 20th century, DACCS may only deliver on the order of 1 Gt CO_2 of global removal capacity by 2050 [89]. In comparison, global oil and gas CO_2 emissions accounted for 20.5 $GtCO_2$ in 2024 [90]. In fact, analysis based on the IPCC scenario literature

suggests a "sustainable range" of 7–9 Gt CO_2 of removals from all types of CDR in 2050 [14,19] - and these only to compensate for residual emissions in "hard-to-abate" sectors, which the oil and gas sector and its products are not normally associated with [91]. Thus the high expectations being placed on DACCS by oil and gas firms appear to be severely misplaced, at least in the mid-term. This suggests that rhetoric and action around DACCS appears to follow - at best - a "Prepper" hedging logic (Direction 3 in Fig. 3), where climate-related actions are selected to reinforce rather than diversify fossil fuel production.

Finally, it is illustrative to observe which CDR content and frames are absent in reporting across oil and gas firms. As might be expected, and consistent with prior work, we find little reference to the phase out of fossil fuels [8]. On the contrary, we find further evidence that firms underline the importance of fossil fuels and particularly natural gas in their longer-term outlooks of market demand [55]. We also corroborate findings that firms refer to the climate scenario literature and IPCC reports to support this position [34–36], while several even suggest that the (scope 3) emissions associated with their fuels can be neutralised through CDR. Both stances rhetorically justify the continued exploitation of fossil resources, while situating oil and gas firms as responsible players in the climate space.

In terms of limitations, this work is constrained by the fact that while CDR is a known category in the academic literature, it remains a nascent concept in industry and policy discourses, being typically integrated into pre-existing categories and sectors (e.g. forestry, land use, CCS, industrial decarbonisation). In the case of DACCS the concept stands out more, but has only been seriously considered outside of niche discussions in the past few years. The nascent nature of CDR discourse makes it difficult to gather data in comparison to other areas of climate change mitigation. For example, renewable energy technologies are by now a known and prominent category, and this is reflected in superior data on investments, as well as dedicated treatment in financial reports and third-party analysis. As the field develops and more attention is drawn to CDR, it would be important to gather and analyse further empirical material in these domains, while expanding to additional qualitative material such as earning calls, public interviews with executives, social media accounts and advertisements.

A second important limitation is the fact that we analyse only recent annual and sustainability reports published in 2024. This decision is driven by the fact that corporate net zero targets are a relatively new phenomenon that coincide with a phase of national target setting under the Paris Agreement starting around 2021. Of course, CDR methods have a longer history [8]. However, it was arguably the introduction of the net zero concept that has precipitated their uptake in national and corporate target setting discourses. Since experience shows that firms do adjust their climate strategies from year to year, including backtracking on renewable initiatives, it will be important to track how engagement with CDR changes over time and whether shifts can be observed in their directions-of-travel.

Finally, we examine only firms that are members of the OGCI - an organisation premised on supporting decarbonisation and the goals of the Paris Agreement - on the basis that these are among the most likely to have developed CDR strategies. Other samples of firms are possible, but it should be noted that these already include most of the "supermajors" and that they offer a relatively diverse array of headquarter and operational locations and ownership structures.

6. Conclusion

How are oil and gas firms integrating carbon dioxide removal into their climate strategies? In this paper, we show that the 12 firms that are part of the Oil and Gas Climate Initiative (OGCI) all maintain nominal net zero targets that typically span Scope 1 and Scope 2 emissions. However, they do not define or strategize about CDR as a distinct category in their 2024 annual and sustainability reports. Rather, individual CDR approaches represent boutique projects with anecdotal and non-comparative operational details. CDR reporting is combined piecemeal into an existing raft of projects and apparent investments covering renewables, EV charging, methane flaring, operational/energy efficiency, CCS, hydrogen of various stripes, and "low carbon fuels" such as biofuels and synthetic fuels.

The fact that oil firms describe these efforts - and the mode in which they do so - can be situated within the widespread private sector turn towards investor-facing environmental, social, and governance (ESG) disclosure and self-regulation. Afforestation/reforestation is the most commonly mentioned CDR approach, often signalling linkages to developing world projects, offsets, and carbon forestry. Occidental, Chevron, and ExxonMobil emphasise DACCS and appear to seek a first-mover advantage in an ecosystem of ostensibly climate-facing strategies that fundamentally prioritise oil and gas production: CCS, blue hydrogen, "lower-carbon" fuels, and EOR.

Recent trends show that certain firms - for example, Shell, BP, and Equinor - are winding down their investments into renewables and returning to core oil and gas competencies in an attempt to compete with Chevron and ExxonMobil, which had already been doing so [92,93]. In general, the (geo)political environment is becoming more permissive towards oil and gas extraction. In an era of increasing multipolarity, imperatives towards energy security are gaining strength. Donald Trump, recently re-elected to the US presidency, has announced intent to increase domestic drilling and has begun to roll back facilitative regulation and incentives for renewables [94]. In 2021, a Dutch lower court ruled that Shell had an obligation to reduce its emissions by 45 % by 2030; the major soon thereafter moved to the UK and even more recently, the Dutch court's ruling was challenged by Shell and struck down [95]. Meanwhile, oil and gas attempts to secure political influence continue apace, as marked by an escalating trend of lobbyist attendance at the annual UNFCCC Conference of the Parties [96].

We therefore sound caution that the oil and gas sector can be relied upon to take the lead in upscaling CDR. The industry is increasingly using CDR as a strategic tool to maintain its operations while presenting itself as environmentally responsible. Elements of this strategy include setting ambitious net zero targets coupled with unclear action and inadequate investments towards them; countering phase-out policies by maintaining that fossil fuels are a long-term necessity, while claiming that they can be part of a 'low-carbon' future if offset by CDR; and shifting attention to "nature-based solutions" or speculative technologies while ignoring difficulties in scaling them.

Rhetoric regarding "nature based solutions" should be considered against a track record of failed carbon forestry initiatives and the so-far limited integration of renewables. Similarly, the prospects of scaling DACCS within a "grey" transition [41] are less promising when considered against the failed history of CCS uptake in the oil and gas sector. To the extent that conventional (ecosystems-based) or novel (engineered, chemical) CDR approaches will be further developed by the oil and gas sector, these will rationalise expanding extraction. If the past is an indication, limited offsetting schemes and boutique innovation or ecosystem services projects will serve as greenwashing mechanisms. If trends of a return to core competencies escalate, then we should be concerned about the stated links between direct air capture technologies, enhanced oil recovery and synthetic fuels. Our assessment indicates that diverse approaches labelled as "climate solutions" - from renewables to CDR - are predominantly used by oil and gas firms as promissory technologies to hedge against decarbonization while largely maintaining the status quo.

In terms of future research, it would be productive to untangle the investment patterns and ownership structures of CDR start ups, including their links to oil and gas firms as well as philanthropic funding. Further, the role of private sector climate governance in facilitating carbon removals remains underexplored, and especially the role of banks and public or private lending in propagating ESG criteria and the associated stringency and transparency of CDR strategies among firms. Above all, it will be important to continually track developments in the

oil and gas sector, and hold major actors to account on their concrete actions to address climate change.

CRediT authorship contribution statement

William F. Lamb: Writing – original draft, Conceptualization, Writing – review & editing, Investigation, Methodology. **Sean Low:** Writing – review & editing, Investigation, Methodology, Writing – original draft, Conceptualization. **Leo-Michael Gordon:** Investigation. **Maisa Mattila:** Investigation.

Declaration of competing interest

The authors have no competing interests to declare.

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Data availability

Data will be made available on request.

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