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Do all roads lead to Paris?
Comparing pathways to net-zero by BP, Shell, Chevron and ExxonMobil

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Abstract

Many oil majors have pledged to reach net-zero emissions by 2050 while transitioning to clean energy. While achieving this requires transformative actions like downscaling hydrocarbon production, offsetting emissions with carbon credits is rapidly mainstreaming as a shortcut to decarbonisation. Although abundant research has contested the climate benefits of offsets, scholarship on oil majors' climate actions has not examined their offsetting activity. We therefore focus on the world's largest publicly traded majors – BP, Shell, Chevron and ExxonMobil – to examine if their net-zero strategies reflect a shift away from fossil fuels and to assess their offsetting behaviour. We firstly use three indicators to examine: (i) the scope of emissions covered, (ii) plans to scale down fossil-fuel production and (iii) reliance on offsets. We then leverage a novel dataset built from company and third-party documents, along with offset-registry data, to assess what offsets are used and how these link to core business activities. Results show that no major's decarbonisation pathway encompasses a business-model transformation away from fossil fuels. This is evidenced by missing plans to curb the production and sales of hydrocarbons and by a reliance on offsets to reach net-zero emissions and to decarbonise energy products. Moreover, results point to questionable climate benefits for offsets, since most derive from historically implemented emissions-avoidance projects that do not physically remove atmospheric carbon in the present. These findings challenge the appropriateness of claims about 'carbon-neutral' hydrocarbons, showing how net-zero strategies omit the urgent task of curbing the supply of fossil fuels to the global market.

Keywords: oil and gas majors, transition, transformation, climate strategy, decarbonisation, offsets

1. Introduction

In recent years, growing numbers of countries, companies and stakeholders are rallying behind the goal of reaching 'net-zero' emissions by mid-century, supporting the Paris Agreement's decarbonisation objectives (Fankhauser et al., 2022, Black et al., 2021, Van Coppenolle et al., 2022, Newell, 2020). Pursuing net-zero typically entails reducing onsite greenhouse gas (GHG) emissions as much as possible, then counterbalancing hard-to-abate or residual emissions with carbon-reduction activities beyond the emissions source. But the road to net-zero should trigger a dual transformation: accelerated deployment of clean energy while downscaling and ultimately phasing out fossil-fuel production (Blondeel et al., 2021). Such a transformation poses an existential threat to the business models of carbon-intensive industries dependent on the extraction, sale and consumption of fossil fuels (Fattouh et al., 2019, Victor, 2021, Stevens, 2016). International and publicly traded oil and gas firms – so-called oil majors like BP, Shell, Chevron and ExxonMobil – are no exception. Indeed, to ensure a 50% chance of limiting planetary warming to 1.5 degrees Celsius, not only is there a need to stop development of all new oil, gas and coal fields (IEA, 2021b), but over half of current oil and gas reserves must remain in the ground (Welsby et al., 2021).

Faced with mounting pressures from activists, investors, lawmakers and others to realign business models with the climate crisis, oil majors based in Europe and North America recently announced plans to achieve net-zero GHG emissions by 2050 (Asmelash and Gorini, 2021, Li et al., 2022). In parallel, they have increased spending on clean energy while deploying marketing strategies built on narratives of pursuing an energy transition (Influence Map, 2019) to become an 'integrated energy company' (Abraham-Dukuma, 2021, BP, 2020c).

Such claims merit careful scrutiny, especially in light of the evidence that oil majors have deliberately sought to obstruct climate action and the shift away from fossil fuels. ExxonMobil (Supran and Oreskes, 2017, Supran et al., 2023), for instance, has strategically

misled the public, politicians and shareholders by denying climate science and propagating misinformation. Evidence also shows that BP, Shell and Chevron have financed lobbying to prevent the introduction of climate policies (Influence Map, 2019, Kenner and Heede, 2021, Brulle and Downie, 2022). Meanwhile, these majors are facing public hearings (U.S. Government, 2022) and lawsuits (Wentz and Franta, 2022), in many cases for misleading public-messaging campaigns that portray a business focus on clean energy and decarbonisation that is larger than actual investments (Influence Map, 2022).

It is difficult to assess the authenticity of the oil majors' promises to achieve net-zero. The details of decarbonisation targets sharing a 'net-zero' label differ considerably (Boon, 2019, Hartmann et al., 2021, IEA, 2020), and aiming to reach zero on a *net* basis risks fostering a mentality that GHG emissions can be compensated with out-of-boundary projects, such as planting trees or installing renewable energy in the global south. This opens the door for carbon offsets (Fankhauser et al., 2022, Coffin, 2020). In an extreme case, a major could claim to have decarbonised its operations and energy supply by simply purchasing or producing its own carbon credits.[1]

Indeed, evidence suggests that oil and gas majors are betting heavily on offsets to survive the transition to a low-carbon economy. Some have announced their intention to use offsets to reach net-zero targets (Tong and Trout, 2022); others are investing capital in carbon-credit developers, while marketing diverse products and decarbonisation services based on these. These include cargoes of 'carbon-neutral' natural gas (Bose et al., 2021, Crook, 2021) and offset programmes for individual drivers, fleet operators and aviation.

This growing reliance on offsets for decarbonising fossil fuels has significant ramifications for climate change and the global energy transition. First, it risks postponing the more difficult – albeit crucial – task of dismantling and rebuilding business models based on oil and gas production (Kreibich and Hermwille, 2021, Böhm and Siddhartha, 2009). Second, and more importantly, both historical and recent evidence shows that many forest-based and technology-based offsets have overstated their climate benefits and thus are unlikely to deliver the 'tonne-for-tonne' emissions compensation claimed by their developers and

[1] This study uses the terms 'carbon credits', 'offset credits' and 'offsets' interchangeably.

buyers (Rathi et al., 2022, West et al., 2020, Cames et al., 2016, Asada et al., 2022, Greenfield, 2023).

The rapidly growing literature on the oil majors' transition activities has several limitations (Canal Vieira et al., 2022, Mahdavi et al., 2022, Kenner and Heede, 2021). First, scholars are yet to examine how the majors are leveraging offsets as a decarbonisation tool, despite this trend attracting considerable attention from news media (Stapczynski et al., 2021, Saiki, 2022), research institutions (Blantin and Mosis, 2021), analysts (Belletti and Schelble, 2022) and NGOs (Crook, 2021). Second, scholars (Green et al., 2021, Hartmann et al., 2021, Pickl, 2019, Zhong and Bazilian, 2018) and stakeholders (Asmelash and Gorini, 2021) have tended to focus on renewable-energy development, viewing this as a central indicator of transition activity. But upscaling renewable-energy businesses addresses only one part of the dual transformation needed to confront climate change. Given the equal imperative to curb the supply of fossil fuels (Trout et al., 2022, SEI et al., 2022, Green and Denniss, 2018), it is important for research to clarify the state of ambitions to reduce oil and gas extraction and sales.

To fill these gaps, we compare the decarbonisation pathways of the world's four largest investor-owned majors – BP, Shell, Chevron and ExxonMobil – to determine if each reflects a transformative shift away from fossil fuels. Our two-tiered analysis asks:

1. *Net-zero strategy*: How do the majors' net-zero plans for 2050 differ with respect to the scope of emissions covered, plans to downscale fossil-fuel production and reliance on offsets?
2. *Offsetting behaviour*: To what extent does each major disclose its offsetting activities? What kinds of offsets are leveraged for decarbonisation and profit generation? How are offsets linked to core business activities?

We pursue these questions using two data sources. Our examination of net-zero strategies draws mainly on evidence from company and third-party documents. Our analysis of offsetting behaviour draws mainly on an original dataset. This dataset describes the core features of offset projects, and it integrates records of credit retirement (buying a credit to claim it as an emissions reduction) from offset registries. Our dataset – the first of its kind – provides in-depth and original evidence to support our claims.

In the following sections, we present the theory and debates underpinning our study before discussing our research design and data sources. We split our results into three sections. The first examines each major's decarbonisation pathway, using three transition indicators. The second analyses the state of offsetting disclosure and the characteristics of offset projects used. The third examines how offsets are used to decarbonise conventional hydrocarbon products, focusing on LNG shipments, driver programmes and aviation. We conclude with a summary of core findings and implications for scholars and stakeholders.

2. Background

2.1 Conceptualising pathways to net-zero

Since around 2020, oil majors have successively announced ambitions to reduce GHG emissions to zero on a net basis by 2050 (Asmelash and Gorini, 2021, Abraham-Dukuma, 2021). Of the four majors studied here, BP was the first to pledge a net-zero goal, in April 2020 (BP, 2020a), two months before Shell (2020b). It took roughly two years for the American majors to follow suit, Chevron (2021a) in late 2021 and ExxonMobil (2022c) in early 2022.

Researchers have conceptualised diverse responses by oil majors to the energy transition and decarbonisation challenge (Boon, 2019, Victor, 2021). These can be broadly placed along a continuum between two contrasting decarbonisation pathways explained below (Hartmann et al., 2021, Zhong and Bazilian, 2018, Shojaeddini et al., 2019). We expect some majors to choose a hedged (i.e. middle-of-the-road) position between the two (Green et al., 2021, Blondeel and Bradshaw, 2022):

1. The *transformative pathway* involves fundamental changes to energy-production methods and business strategies. A prototypical response would entail progressively and substantially downscaling fossil-fuel production while shifting the core business towards clean energy and associated technologies (e.g. green hydrogen, EV charging stations).
2. The *conservative pathway* involves no or limited efforts to downscale fossil-fuel production and shift towards clean energy and associated technologies. Efforts concentrate instead on continuing traditional businesses built on hydrocarbon extraction and sales and on decreasing operational emissions via offsets, carbon capture and storage (CCS) and technological improvement (e.g. methane leak detection).

Scholars and stakeholders have used diverse indicators to compare and classify the heterogeneous responses by oil majors to the energy transition challenge (Green et al., 2021). Some studies emphasise environmental performance, like GHG emissions (Shojaeddini et al., 2019) or the acceptance of climate science and carbon pricing (Mahdavi et al., 2022), whereas others examine spending or emphasis on clean energy (Shojaeddini et al., 2019, IEA, 2020, Hartmann et al., 2021). Still others measure exploration activity (Li et al., 2022, Tong and Trout, 2022) or targets to reduce GHG emissions on an absolute basis (Coffin, 2020, Asmelash and Gorini, 2021).

Table 1 Core indicators for determining decarbonisation pathways based on net-zero strategies

Does the major's net-zero strategy include plans to…?	**If 'yes'**	**If 'no'**	**Is this strategy consistent with a transformative pathway?**	**Basis in literature**
1. Reduce scope 3 emissions from all energy products sold?	Creates a strong need to reduce emissions via 2) or 3)	Allows the continuation of existing fossil fuel businesses	Yes	(Victor, 2021, Li et al., 2022, IEA, 2020, Coffin, 2020)
2. Reduce the supply of fossil fuels, covering production and sales?	Reduces the need to rely on offsets (3)	Increases the need to rely on offsets (3)	Yes	(Li et al., 2022, Tong and Trout, 2022, Mahdavi et al., 2022)
3. Use offsets to reach the net-zero target?	Allows a major to retain its core business model focused on fossil fuels and reduces the need to replace with non-fossil energy (2)	Increases the need to reduce fossil fuel production (2) and replace with non-fossil energy	No	(Boon, 2019, Tong and Trout, 2022)

Though such indicators provide important cues about a major's chosen decarbonisation pathway, this perspective, by focusing on actions related to clean energy and decarbonisation, addresses only one part of the energy transition equation. Considering the abundant literature on tackling climate change through *supply*-side actions (Green and Denniss, 2018, Newell and Simms, 2019, Piggot et al., 2018), there is also a need to examine the presence of strategies to progressively downscale the production and sale of oil and gas (IEA, 2021b, Crook, 2021, Green et al., 2021). Moreover, few scholars have examined reliance on offsets, which arguably provide a clear-cut indication of a major's willingness to shift away from fossil fuels.

Guided by these insights, this study fixes three simple indicators to determine each major's

decarbonisation pathway based on core features of its net-zero strategy:

1. *Emissions*: Does the major's net-zero strategy cover scope 3 emissions from all energy products sold? ('Yes' in a transformative pathway.) This indicator recognises that over 80% of lifecycle emissions for oil and gas are so-called scope 3 and occur during end-use combustion (IEA, 2020). Including these emissions thus reflects a higher ambition on decarbonisation than if limiting to scope 1 and 2.[2] This indicator also reflects expectations that corporate net-zero targets encompass scope 3 emissions (Day et al., 2023, SBTi, 2020, Black et al., 2021).
2. *Fossil-fuel supply*: Does the major plan to reduce the supply of fossil-fuel production and sales? ('Yes' in a transformative pathway.) This indicator interprets the task of reducing the supply of fossil fuels, from the perspective of both production and sales. This reflects majors' tendencies to sell oil and gas produced by third parties (Liauw et al., 2022a).
3. *Offsets*: Will the major use offsets to meet decarbonisation targets? ('No' in a transformative pathway.) This indicator recognises that using offsets is a short-term and end-of-pipe strategy that delays the more arduous and costly task of shifting systems of energy production and supply to carbon-free sources (Kreibich and Hermwille, 2021, Bose et al., 2021).

Together, this trio of indicators provides a streamlined litmus test to clarify whether each major's decarbonisation pathway is aligned with the necessary dual transformation of simultaneously *increasing* renewable energy and *decreasing* its fossil-fuel supply (Blondeel et al., 2021, Crook, 2021). The extant literature, being focused on renewable energy and climate strategies, has not exhaustively clarified this (Green et al., 2021, Li et al., 2022, Kenner and Heede, 2021, Dietz et al., 2021). We anticipate considerable interdependence and causality between the three indicators (**Table 1**). For instance, including scope 3 emissions in the net-zero target triggers a strong need for actions that bring large gains in decarbonisation, like reducing fossil-fuel production or compensating emissions with offsets. Conversely, omitting the scope 3 portion from net-zero targets avoids the need to reduce the carbon content of fossil fuels. This in turn weakens any imperative to downscale fossil-fuel production or rely on offsets, since technological optimisation can eliminate most scope 1 and 2 emissions.

[2] Scope 1 covers emissions from sources that an organisation owns or controls directly. Scope 2 emissions are caused indirectly via energy purchased from other parties (e.g. grid electricity purchased for use in oil refineries). Scope 3 encompasses emissions that arise not from the company's operations but from its products when used by end consumers. For the oil industry, this refers to emissions that result from the end-use combustion of the hydrocarbon products it sells.

2.2 Offsets as a response to the energy transition

Carbon offsets and net-zero are tightly linked, complementary concepts (Carton et al., 2022, Seddon et al., 2021). Both operationalise the idea that since eliminating all in-house GHG emissions is technologically difficult and costly, residual or hard-to-abate emissions can be compensated (i.e. offset) by reducing or capturing atmospheric emissions in a location beyond the emissions source (Black et al., 2021, Fankhauser et al., 2022, Bumpus and Liverman, 2008).

Four forces in particular have fuelled the mainstreaming of offsetting as a decarbonisation approach. First, the Kyoto Protocol, through its Clean Development Mechanism (CDM), propagated the practice of industrialised countries cutting their emissions with carbon credits produced from technological interventions in developing countries (e.g. capturing landfill gas or installing renewable energy), where abatement costs are lower (Anderson, 2012, Green, 2013, Böhm and Siddhartha, 2009, Bumpus and Liverman, 2008). Second, the United Nations' Reducing Emissions from Deforestation and Forest Degradation (UN-REDD) programme promotes the generation of carbon credits from forestry projects, especially in tropical countries. Norway has long championed this mechanism as a means of offsetting its emissions, including those from its oil and gas industry (Røttereng, 2018, Lang, 2022). Third, offset developers have played an active role in growing the global offset market (also called the 'voluntary carbon market'), principally by expanding the supply of cheap offsets available for companies to buy and count towards emission reductions (Victor and Cullenward, 2020, Valiergue and Ehrenstein, 2022). This market has grown rapidly: the 166 million t-CO_2e worth of offset credits retired in 2022 is a doubling of the market size in 2019. Some analysts predict that the value of the market – currently around $2 billion (BloombergNEF, 2023) – will grow 100-fold by 2030 (Morgan Stanley, 2022).[3] Fourth, through its emphasis on carbon neutrality, the Paris Agreement has triggered demand for credits by prompting the proliferation of net-zero pledges and carbon regulation (Valiergue and Ehrenstein, 2022). The Paris Agreement is expected to continue propelling growth of the voluntary carbon market in the coming years, notably through Article 6, which allows countries to meet emission reduction goals by trading credits (Shell and BCG, 2023).

Projects that generate offset credits can be categorised into: (1) those that avoid emissions and (2) those that directly remove carbon from the atmosphere (**Table 2**). Both nature-based and technology-based approaches can operationalise these objectives.

[3] All dollar units herein are US.

Table 2 Examples of different approaches to offsetting

	Emissions avoidance	Emissions removal
Nature-based		
Avoided deforestation	✓	
Afforestation		✓
Technology-based		
Renewable energy project	✓	
Carbon capture and storage (CCS)	✓	
Bioenergy with carbon capture and storage (BECCs)		✓*
Direct air capture (DAC)		✓*

Note: Based on various sources (Trove Research, 2021b, Allen et al., 2021, Carton et al., 2022, Bose et al., 2021). Asterisks denote removal approaches with potential to permanently store atmospheric carbon in geological or deep ocean repositories.

With emissions avoidance, nature-based approaches typically involve forest-conservation projects in developing countries that claim to reduce carbon emissions by preventing deforestation (Seddon et al., 2021). Alternatively, a technology-based project might install renewable electricity in a country developing its power grid or distribute fuel-efficient cooking stoves that reduce firewood consumption in a rural village. Importantly, generating offset credits from avoidance projects involves the contentious task of estimating emissions in a business-as-usual scenario, where a particular offsetting intervention never went ahead (Carton et al., 2022). But because this counterfactual world cannot be directly observed, estimates of carbon reduction are prone to inaccuracy, subjectivity and overstatement (Allen et al., 2021, Stein and Merchant, 2022, West et al., 2020). Besides, with a financial motivation to generate as many credits as possible, project developers may purposely exaggerate historical baselines or the period for which avoided emissions are claimed (Green, 2021).

The alternative to avoidance involves *physically* removing carbon from the atmosphere, then storing it in terrestrial or geological sinks. Nature-based projects can achieve this via afforestation, ecosystem restoration or soil enhancement. Technology-based projects may

draw down and sequester atmospheric carbon with direct-air-capture technology (IEA, 2022) or couple bioenergy with carbon capture and storage (BECCS).

Scientists and voluntary-carbon-market actors provide clear suggestions regarding the assessment of offset quality from a climate mitigation perspective. There is wide agreement that a 'quality' offset is one that: (1) directly *removes* atmospheric carbon, ensuring storage over centuries or millennia, and (2) derives from a *recently* implemented offset project (Allen et al., 2021, Green Finance Observatory, 2020, Hong et al., 2022, Carton et al., 2022, Day et al., 2023). Conversely, offsets relying on claims about avoided emissions or originating in old projects bring fewer climate benefits (Pearce, 2021, Turner and Grocott, 2021, Stapczynski et al., 2021, Rathi and White, 2022). Having stipulated such indicators, we recognise that the offsets in mainstream use are unlikely to meet such quality standards or to offer an effective substitute for reducing emissions in-house (Day et al., 2023, Carton et al., 2022). This is essentially because all offset approaches inherently entail considerable difficulties in ensuring permanent storage, additionality and 'tonne for tonne' compensation.

On removal versus avoidance, the international Science Based Targets initiative, which sets guidelines for corporations aiming for net-zero, has stipulated that avoidance offsets must 'not count' towards emissions reductions (SBTi, 2021: 42). The emphasis on removal recognises that claiming to have prevented past or future emissions does not provide the same benefits for climate mitigation as actually drawing down atmospheric carbon today (Anderson et al., 2019, Hong et al., 2022). However, all biological carbon sinks are prone to leakage or reversal, for instance as forests wither from age or if agricultural soil-management techniques change. The only methods that offer permanent storage potential are those that couple geological storage with technologies like direct air capture (DAC) or bioenergy combined with carbon capture (BECCS) (see asterisks in **Table 2**). Yet such removal techniques suffer from technological immaturity and high costs (Stein and Merchant, 2022) and are yet to be deployed at scale (IEA, 2022, Hong et al., 2022).

With respect to age, the UN's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) limits eligibility to those issued after January 2016 (ICAO, 2022). This rule reflects recognition of the innate problems with historical offsets. One problem is that the older the credit, the more difficult it becomes to prove its efficacy for carbon reductions, accounting methodology and additionality (Turner and Grocott, 2021). CORSIA's stance also recognises that accounting methodologies and project-monitoring

mechanisms have improved. More importantly, limiting offsetting to recently implemented projects assures that funds are directed to contemporary actions that compensate for emissions produced today (Hong et al., 2022). This avoids the converse situation, where the purchase of 'legacy' or 'zombie' credits from historical projects does nothing to tackle the problem of GHGs accumulated in the atmosphere today (Pearce, 2021).

3. Research design

3.1 Case selection and novelty

Our focus on BP, Shell, Chevron and ExxonMobil is justified by their status as the world's four largest investor-owned oil majors. It also recognises their collective contribution to climate change, since their combined energy products are responsible for 12% of global fossil-fuel emissions since 1965 (Kenner and Heede, 2021). Our case selection also covers trends in Europe and North America. This furthers knowledge on previously identified geographical differences with respect to energy transition behaviour (Li et al., 2022, Green et al., 2021, Victor, 2021). Beyond this, we advance understanding of the heterogeneous responses of different majors by providing the most in-depth analysis of offsetting behaviour to date. Our case selection equally suits this task, since the scale of offset retirements by BP, Shell and Chevron places them among the world's ten largest consumers of offsets.[4]

3.2 Data sources

Our dual analysis of net-zero strategies and offsetting behaviour draws on three sources of evidence: (1) documents from each major (annual reports; reports related to transitioning, sustainability and other topics; press releases; and websites); (2) documents from third parties (reports from think tanks, consulting firms and NGOs, and academic literature); and (3) public records of offset retirements from registries in the voluntary carbon market.

3.3 Offsetting behaviour analysis

Our examination of offsetting behaviour targeted the projects used by each major to procure carbon credits between January 1, 2020, and December 31, 2022 ('the study period'). This three-year period captures the increase of offsetting activities since 2020 due to net-zero aspirations (Victor, 2021). We also examined the volume and attributes of credits retired from these projects. The limited nature of voluntary disclosure in offset

[4] The authors' calculation for the year 2021, based on Rathi et al. (2022) and BP's and Shell's responses to the Climate Change survey by the Carbon Disclosure Project (CDP).

registries, especially by BP, prevented an exhaustive analysis of retirement activity. Focusing on the defining attributes of offset projects allowed us to overcome this 'missing data' gap.

The offsetting analysis proceeded with four steps. First, we searched company documents published by each major for mentions of offset projects used – whether for self-decarbonisation, provision to clients or value generation. We then identified additional projects from the credit retirements recorded in the four main registries in the voluntary carbon market where we observed retirement activity (American Carbon Registry, UN-CDM, Gold Standard, Verified Carbon Standard), along with questionnaire responses submitted to the Carbon Disclosure Project (CDP) for climate change in 2020–2022.[5]

Second, we built an original dataset that integrates the core attributes of identified offset projects with records of credit retirement (**Supplementary Information 1**). We triangulated our findings with proprietary data, purchased from an analysis firm (Allied Offsets), that provides detailed project-by-project and company-by-company data on offset projects and retirements.

Third, we analysed our dataset from three aspects: (1) the extent to which each major voluntarily discloses, in documents and public registries, the volume and nature of offset projects used and credits retired; (2) the type of emissions reduction (avoidance or removal), and (3) the age of offset projects. Our interest in the first aspect stems from expectations from industry-led governance frameworks (TSVCM, 2021, IIGCC, 2023) and stakeholders (Day et al., 2023) that companies disclose all offsetting activity.[6] Full transparency on the volume and type of offsets used is a critical tool for enabling stakeholders to monitor the scale of a major's offsetting activity compared to other decarbonisation actions, and to assess the quality of offsets used. The last two aspects – emissions reduction type and age of offset projects – verify if the projects (and their credits) correspond with best-practice principles that emphasise carbon removal over avoidance and the need for recently implemented carbon-reduction activities (Allen et al., 2021, Hong et al., 2022, Carton et al., 2022, Turner and Grocott, 2021, SBTi, 2021, Day et al., 2023).

[5] Organised by the non-profit body CDP, these questionnaires are a voluntary means by which companies disclose climate-related information to stakeholders and investors. Responses were available only for BP and Shell, since Chevron and ExxonMobil do not participate in this survey.

[6] Being a voluntary market, disclosure to the public about the offset projects used and the volume of their retirements made is not mandatory. Instead, it is desirable from the perspective of transparency and good practice.

When classifying forestry projects into removal/avoidance, we recognise that some UN-REDD projects remove carbon in addition to their primary function of avoiding emissions caused by forest destruction. We dealt with this by adopting project classifications from Atmadja et al. (2022), coding the dominant approach (avoidance or removal) based on project surface area. For other types of forestry projects, we coded the dominant approach using classifications from Allied Offsets or evidence from project documentation. Our analysis of project age focuses on the start year of the first crediting period.[7] We designate January 1, 2016, to identify historically implemented projects that do not satisfy requirements stipulated by the UN's CORSIA framework governing offsetting in the global airline industry (ICAO, 2022). Though it provides an easy-to-apply and coarse-grained estimate of the age of climate benefits generated by offset projects, using the first crediting period has limitations, since it does not consider the 'vintage' year of credits retired. The latter, by capturing the particular time that an emissions reduction occurred, is arguably a better measure of the age of an offset project's climate benefits. This is particularly relevant for tree-planting projects, which provide important emission reductions today as trees grow – even when these projects started many years ago. We addressed this limitation by also examining the vintage years of offset retirements, when disclosed. Data availability challenged this, however, because vintage years are not provided by UN's CDM registry data and because we were unable to identify substantial volumes of credit retirements for BP and ExxonMobil in registries.

Fourth, and finally, we have triangulated our methods and results through consultations in which we presented our methods and results to six anonymous experts working in the offset market. These are five consultants and researchers at two data firms in Europe and North America, and one researcher at a Europe-based think tank. We used their advice to improve our methodology and interpretations of results.

[7] The start year of the first crediting period captures the time when activities that created carbon reductions or avoidance began (e.g. the year the first tree was planted, in the case of an afforestation project).

4. Results

4.1 Characterising decarbonisation pathways

This section examines each major's net-zero strategy through the three indicators fixed in **Table 3**. Overall, we find no net-zero strategy that convincingly indicates a transformation pathway, as discussed in **Section 2.1**. Though communication and investment tactics create a narrative of pursuing an energy transition, each major plans to continue its fossil-fuel businesses in the coming decades while using offsets to propel progress towards net-zero targets or to decarbonise conventional hydrocarbon products. Furthermore, by omitting scope 3 emissions or by formulating decarbonisation targets based on carbon intensity, no plan is likely to achieve a meaningful decline in absolute GHG emissions over the next decade or so (Liauw et al., 2022a).

Table 3 Overview of net-zero strategies

	Does the net-zero strategy aim to reduce scope 3 emissions from all energy products sold?	**Does the net-zero strategy plan to downscale the supply of oil or gas?**		**Does the net-zero strategy use offsets for decarbonisation targets?**		**Decarbonisation pathway**
		Production	**Sales**	**2030**	**2050**	
BP	✓	✓ (oil and gas)	×	×	✓	Middle-of-the-road
Shell	✓	✓ (oil)	×	✓	✓	Middle-of-the-road
Chevron	×	×	×	✓	✓	Conservative
Exxon Mobil	×	×	×	✓	✓	Conservative

BP, pledging to shift investments progressively towards clean energy while reducing oil and gas production (BP, 2022a, BP, 2020c), gives the impression of pursuing a transformative decarbonisation pathway. However, closer inspection suggests this is a middle-of-the-road strategy, since several loopholes allow BP to retain its fossil-fuel operations while transitioning. Since February 2022, BP's net-zero target includes scope 3 emissions for all energy products sold or marketed (BP, 2022a). BP has also pledged to reduce total fossil-fuel production by an expected 25% in 2030 from 2019 levels (BP, 2023a). This, however, weakens its previous commitment to reduce production by 40% by 2030 (BP, 2022d), which it made before the surging energy demand and prices following Russia's invasion of Ukraine.

BP's downscaling strategy relies principally on divestment, by selling upstream assets like oil and gas fields. But there is no guarantee that simply selling these assets to other producers has a positive climate impact or, indeed, that these reserves would then be 'kept in the ground' (Colgan et al., 2021). To the contrary, there is evidence that in certain regions, like the North Sea, upstream asset ownership has shifted from publicly traded majors, like BP, to private or nationally owned companies that operate far more opaquely and with less public scrutiny over their climate responsibilities (Bridge and Dodge, 2022).

Moreover, BP does not aim to reduce the volume of fossil-fuel products *sold*. For BP, this is important, because sales of third-party energy products exceed its self-produced oil and gas by around 50% – a much higher ratio than for other majors (Liauw et al., 2022a). Also, BP forecast that third-party oil and gas sales along with associated emissions will increase until 2030 because of plans to upscale transport-fuel sales 'in fast-developing markets' (BP, 2020b). Like Shell and Chevron, BP's scope 3 emissions target is intensity-based rather than absolute. Consequently, increased sales of fossil fuels may raise its absolute emissions over the next decade (Liauw et al., 2022b, Comello et al., 2021). In early 2023, BP updated its goal for scope 3 emissions (i.e. 'aim 2'), pledging a 20%–30% reduction by 2030 on an intensity basis (BP, 2023b). But like its backtracking of commitments to downscale fossil-fuel production, this updated scope-3-emissions target has softened the previous pledge, set in 2020, which originally aimed for a 35%–40% reduction by 2030.

With respect to offsets, BP has explicitly said it will not rely on these to meet decarbonisation targets for 2030 (BP, 2021c). But it hints at needing them to achieve net-zero targets for 2050: '[offsets] may help us to go beyond those [2030] aims if we can' (BP, 2021c). It also emphasises nature-based offsetting in its transition strategy (BP, 2023a). BP is actively harnessing offsets as a decarbonisation device to compensate for emissions arising from the production and use of hydrocarbon products like LNG and lubricants, marketing these as 'carbon-neutral'. Like Shell, BP is working to generate revenue by supplying offsets to other parties. To this end, it advocates for growth of the voluntary carbon credit market and the use of offsets for decarbonising other industries (BP, 2021c). It leverages a portfolio of nature-based and technology-based projects via its Target Neutral initiative to provide offsets for vehicle fleets, event operators (e.g. concerts) and individuals (BP, 2019). BP is also investing in the development of carbon credits. For example, it has acquired a majority stake in Finite Carbon, an American-based developer of forestry offsets.

Shell, too, claims to be transitioning and has pledged to increase spending on clean energy (Shell, 2021e, 2021f). The evidence, however, suggests that it has also chosen a middle-of-the-road decarbonisation pathway. On the one hand, its net-zero target includes scope 3 emissions for all energy products on an intensity basis – including those produced by Shell and third parties (Shell, 2022a). The major also forecast in 2021 that oil production would decline at 1%–2% annually until 2030 (Shell, 2021e). On the other hand, like BP, the board of Shell is reported to be considering the feasibility of watering down this commitment following increased opportunities for record oil and gas profits since the Russian war in Ukraine (Gosden, 2023, Strasburg, 2023). Shell has also been working to increase gas's share of total hydrocarbon production to 55% by 2030 (Shell, 2021d). Given this, some analysts predict that its absolute gas production will grow around 4% annually in the coming years (Ambrose, 2021, Liauw et al., 2021). Shell has no target to reduce the volume of its oil and gas *sales* (Liauw et al., 2022c). Thus Shell, like BP, lacks an integrated strategy to downscale its overall supply of oil and gas.

Shell has explicitly stated it will leverage offsets to meet net-zero targets in 2030 and 2050 (Shell, 2021f). Specifically, it aims to retire 120 million carbon credits annually by 2030 through nature-based projects (Shell, 2021f). The scale of this ambition is staggering. To put it in perspective, consider that the volume of offsets retired from the entire *global* voluntary market in 2022 is 156 million t-CO_2e and that nature-based projects newly issued only 93 million credits (Climate Focus, 2023). Shell also pledged in 2019 to spend $300 million on offsetting over three years (Shell, 2019a). It has made progress towards these targets. For instance, it spent $92 million in 2022 to purchase a total of 5.8 million carbon credits, of which 4.1 million were used to reduce its own carbon intensity (Shell, 2023).

Shell also pairs offsets with numerous hydrocarbon products that claim carbon neutrality during production and consumption. Besides LNG cargoes, these include lubricants, gas-to-liquid fuels and bitumen (Shell, 2022c). To this end, Shell, like BP, draws on a broad portfolio of nature-based and technology-based offset projects. It is also actively acquiring equity in and partnering with third-party offset developers, such as Select Carbon, a specialist in agricultural soil-enhancement projects (Shell, 2020c). Beyond self-decarbonisation, Shell harnesses carbon credits as a value-generation tool, ardently promoting offsetting as a tool for reaching net-zero. It has published numerous reports that champion offsetting in carbon-intensive industries like road-transport fleets and aviation, while advocating for expansion of the voluntary carbon market (Shell, 2021b, Shell and BCG, 2021, Shell, 2021a).

Chevron and ExxonMobil have unequivocally chosen a conservative pathway. Though each has announced the intention to pursue a net-zero target and increase clean-energy spending (Chevron, 2021b, ExxonMobil, 2022b), their strategies lack the ambition of their European counterparts. First, not only have Chevron and ExxonMobil omitted scope 3 emissions from their 2050 targets, but semantically, each describes its net-zero goal as a mere 'aspiration' and 'ambition' (ExxonMobil, 2022b, Chevron, 2021a). Second, both continue to express intentions to grow their conventional hydrocarbon businesses (ExxonMobil, 2020, Chevron, 2023a). In March 2022, ExxonMobil told its shareholders that hydrocarbon production would grow from 3.8 million oil-equivalent barrels per day to 4.2 million in 2025 (ExxonMobil, 2022a). Chevron promised its investors in February 2023 that it would increase combined oil and gas production at least 3% annually until 2027 (Chevron, 2023b). To leave room for expanded production, Chevron and ExxonMobil, like the European majors, base their emissions reduction targets on carbon intensity. Chevron's annual report unabashedly admits this objective, explaining that intensity-based targets give it 'the flexibility to grow' its hydrocarbon production and sales (Chevron, 2022a).

Chevron too has stated intentions to leverage carbon offsets for meeting net-zero targets (Chevron, 2021b). It even says that the feasibility of its net-zero strategy 'depends on' the 'availability of cost-effective, verifiable offsets in the global market' (Chevron, 2022b). Chevron especially champions the use of nature-based solutions, partnering with the European majors to launch the advocacy platform Markets for Natural Climate Solutions. Compared to ExxonMobil, Chevron has issued multiple and more explicit statements about its intentions to generate profits by investing upstream in the offset value chain (Chevron, 2022b). For example, it has set a target to develop 25 million tonnes of credits each year by 2030 (Chevron, 2023b). It is also acquiring equity in specialist offset developers, one being Boomitra, a start-up in Silicon Valley engaged in soil-based methods for carbon removal (Chevron, 2021c). It is also co-implementing a tree-planting project in Louisiana with Restore the Earth Foundation in the goal of supplying offsets to third parties (Chevron, 2022c). Additionally, as described in **Section 4.2**, Chevron has started offering offsets to individual motorists through its gasoline-station network in Singapore (Chevron, 2022e).

Like Chevron, ExxonMobil has underscored offsetting as a core tool for meeting its net-zero targets, including milestones for 2030 (ExxonMobil, 2022b, ExxonMobil, 2023). It also pledged in 2021 to allocate $3 billion leading up to 2028 for offsets and carbon capture

(Holland, 2021). Beyond such statements, however, there is scarce information about ExxonMobil's offsetting activities and future intentions. It does not appear committed to developing and selling offsets to other parties. And unlike the other three majors, it has not yet publicly announced any investments in third-party carbon credit developers.

4.2 Offsetting behaviour

Here, we firstly describe the extent to which the majors voluntarily disclose their offsetting activity. Then we analyse the quality of their offsets based on two measures (see **Section 2.2)**: (1) the use of avoidance versus removal projects; and (2) the age of offset projects and credits. Four core findings flow from the data (see also **Supplementary Information 1**).

First, we find sharply contrasting levels of disclosure about offsetting activity (**Table 4**). Disclosure was interpreted from two perspectives: (1) the act of communicating involvement with a specific offsetting project in communication materials (annual reports, websites, press releases, etc.); and (2) the act of publicly disclosing offset retirements on registry databases.[8] Findings suggest a need for greater transparency from both perspectives.

BP and Shell disclose their offset project portfolios most actively in communication materials. But BP is highly opaque about disclosing actual credit retirements. During the study period, it disclosed only 26,964 t-CO_2e of retirements in registries. These originated from two projects used by its subsidiary, BP Technology Ventures. For the remaining 22 projects disclosed in communications material, BP's name is not listed as a retiree or beneficiary in registries. Shell has disclosed the most, both in communications (55 projects) and in registries (22 projects), with the latter totalling 9.88 million t-CO_2e. However, retirement data for 33 projects did not turn up in our analysis. Shell also claims to have retired 11.8 million credits in 2021 and 2022 (Shell, 2021e, Shell, 2023), but we could only identify 7.83 million tonnes in registries for this period.

Chevron's case also indicates limited transparency, but in the other direction. Though it mentions involvement with only four registry-listed offset projects in its communication

[8] When retiring offsets from publicly disclosed carbon offset registries, the retiree (or beneficiary) can choose to either disclose or conceal their name and the reasons for retirement (see **Supplementary Information 2 Table 1**). In cases where a major does not list its name in connection to a specific credit retirement, it is unclear whether this is done to escape public scrutiny or because credits were purchased via intermediaries, procured directly from self-developed projects, or provided to customers.

materials, our analysis of registry data revealed that Chevron is actively retiring credits. Derived from 17 projects, these total 3.40 million t-CO_2e over the study period. Retirement reasons provided in registries explain this situation: they indicate that Chevron has principally used offsets to lower its emissions under Colombia's carbon tax rather than to pursue its net-zero targets. Finally, we found no evidence of meaningful engagement by ExxonMobil with offsetting activities. This major does not mention any specific and registry-listed project in communication materials and has disclosed only 6 t-CO_2e from one project.[9] Because of this lack of evidence of strategic use of offsets for decarbonisation or provision to other customers, we omit ExxonMobil from the remaining analyses.

This state of disclosure – particularly the limited and inconsistent availability of *credit retirement* data on offset registries – has restricted the depth of our analysis. To overcome these hurdles, the following analyses focus on BP, Shell and Chevron and the attributes of offset projects per se. Where possible, data on credit retirements is used as corroborating evidence.

Our second core finding is prolific use of avoidance offsets (**Figure 1**) that do not physically capture atmospheric carbon. Of the 116 offset projects identified in communications materials and offset registries, 85 (73%) are primarily avoidance-based. This trend is especially pronounced for BP and Chevron. BP's portfolio of 25 projects does not include a *single* project based on carbon removal. For Chevron's portfolio of 19 projects, only *two* projects (both afforestation) involve direct carbon removal. Shell's portfolio also leans towards avoidance, which constitutes 43 (60%) of 72 projects.

Preferences for avoidance projects are even more apparent in data on credit retirements (**Figure 2**). For Shell, 85% of 11.18 million credits retired since January 2020 are avoidance-based. For BP and Chevron, this rises to 100%. The observed prevalence of avoidance credits is likely explained by their plentiful supply and low cost – often sold for $4–$6 per tonne.[10] Carbon removal projects, meanwhile, mainly consist of more costly afforestation or ecosystem restoration projects (Stein and Merchant, 2022).

Third, we found no instances where a major uses offset credits with technology-based carbon removal (**Figure 1**). As mentioned in **Section 2.2**, these are the only approaches

[9] Inner Mongolia Ximeng Zheligentu Wind Farm Phase I Project, listed on the Verra VCS registry.
[10] All dollar units in this paper indicate US dollars.

that offer potential for permanent removal and sequestration of carbon. Although Chevron is investing in direct air capture development with its Climate Engineering venture, and the other majors are also likely investigating removal technologies, no offsetting project identified in communication materials or retirement data involves the removal of atmospheric carbon with technology. This finding undoubtedly reflects various restrictions. Not only are removal technologies immature, but offsets are scarce, expensive and not available on the main carbon registries (Stein and Merchant, 2022, Carton et al., 2022). Nevertheless, it is notable that companies such as Microsoft, United Airlines and Airbus have started to purchase credits from technology-based removal via other registries, or position this approach as central to future offsetting strategies (IEA, 2022).

Fourth, we find that BP, Shell and Chevron have relied predominantly on historical offset projects, most having credit-issuance periods that began before 2016 (**Figure 3**). Since the climate benefits generated by these projects began several years ago, their suitability for compensating contemporary carbon emissions is questionable. Specifically, offsetting projects that started before 2016 make up 92% of those mentioned by BP, 72% for Shell and 89% for Chevron. We thus find that the offset credits used by the majors to compensate for contemporary emissions do not comply with CORSIA's age standards, which prohibit the use of credits issued before January 2016.

Although BP, Shell and Chevron have disproportionately selected aged offset projects, there remains a possibility to tap into recently generated emissions reductions by purchasing newly generated credits. To check this, we examined the distribution of 'vintages', which indicate the year during which an offset project's climate benefits occurred (see **Supplementary Information 2, Figure 1**). With data available only for Shell and Chevron,[11] results show that both majors are principally retiring historical credits: 93% of the credits retired by Shell with identifiable vintages were issued in or before 2014, while 64% date back to 2012 or earlier. The credits purchased by Chevron are more recent, but these too contain a large share of historical credits: of the 3.4 million credits retired since 2020, 90% have vintages of 2017 or older, while 39% date back to 2015 or earlier.

In sum, despite the majors' claims of sourcing only 'quality' offsets (Shell, 2021b, Chevron, 2022d, BP, 2022a), our analysis indicates that the bulk of projects and carbon credits

[11] We were unable to analyse vintage years for BP for two reasons: (1) the UN-CDM registry where we found two cases of credit retirement totalling 26,694 t-CO_2e does not list this information, and (2) it does not disclose other retirements on registries.

leveraged by BP, Shell and Chevron provide, at best, dubious climate benefits due to the widespread use of both historical and avoidance activities. These findings challenge the appropriateness of using such offsetting projects as a basis for claiming that a company's contemporary fossil-fuel activities add no net carbon emissions to the atmosphere.

Table 4 Summary of voluntary disclosures about offsetting activity (January 2020 to December 2022)

	Disclosed in communications	**Disclosed in registries**	**Not disclosed in registries**	**Not disclosed in communications**	**Total retirement volume disclosed (t-CO_2e)**	**Summary of disclosure**
Explanation	Projects mentioned on website or documents published since January 2020	Projects for which retirements over 2020-22 were identified on public registry	Projects disclosed in communication materials but not identified or disclosed on registries	Projects disclosed in registries but not identified in communications	Sum of all retired credits recorded on registries since Jan 2020	
BP	22	2	22	2	26,694	More in communications than in offset registries
Shell	55	22	33	2	9,879,595	More in communications than in offset registries
Chevron	4	17	1	14	3,400,908	More in offset registries than in communications
ExxonMobil	0	1	0	1	6	None in communications and virtually none in public registries

Note: The numbers listed in this table do not include offset projects for which registry information (i.e. registry name, project ID, etc.) was not identified in either one of the four registries we consulted. Also, due to our focus on voluntary transaction-level disclosure in public registries, the column 'Total retirement volume disclosed (t-CO_2e)' does not include data submitted by BP and Shell to the annual CDP Climate Change questionnaire.

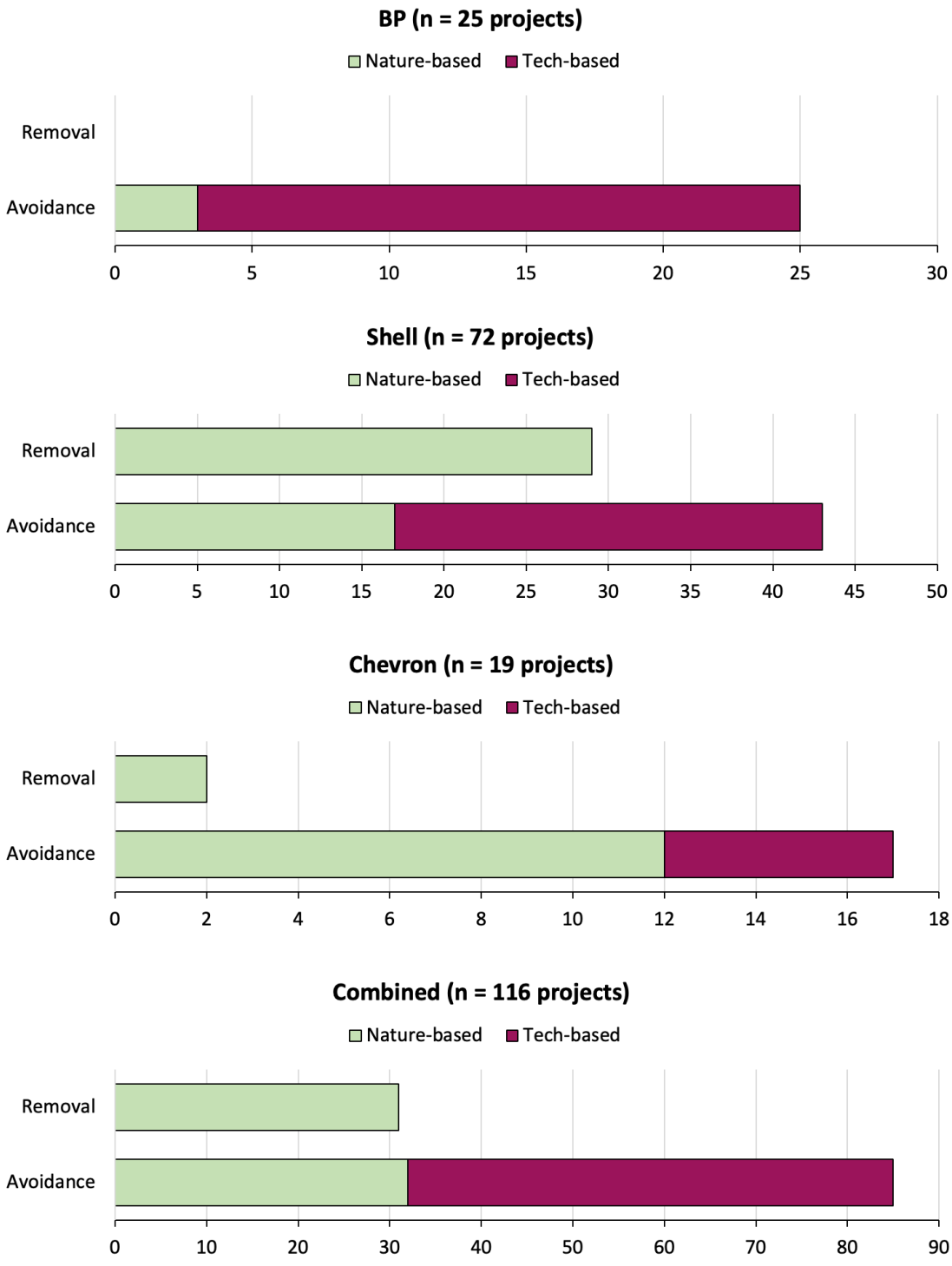

Figure 1 Type of offset projects used or reported in communication materials (1 January 2020 to 31 December 2022)

Note: X-axes show number of offset projects. See Research Design (Section 3.3) for explanation of coding of removal/avoidance for forest-conservation projects.

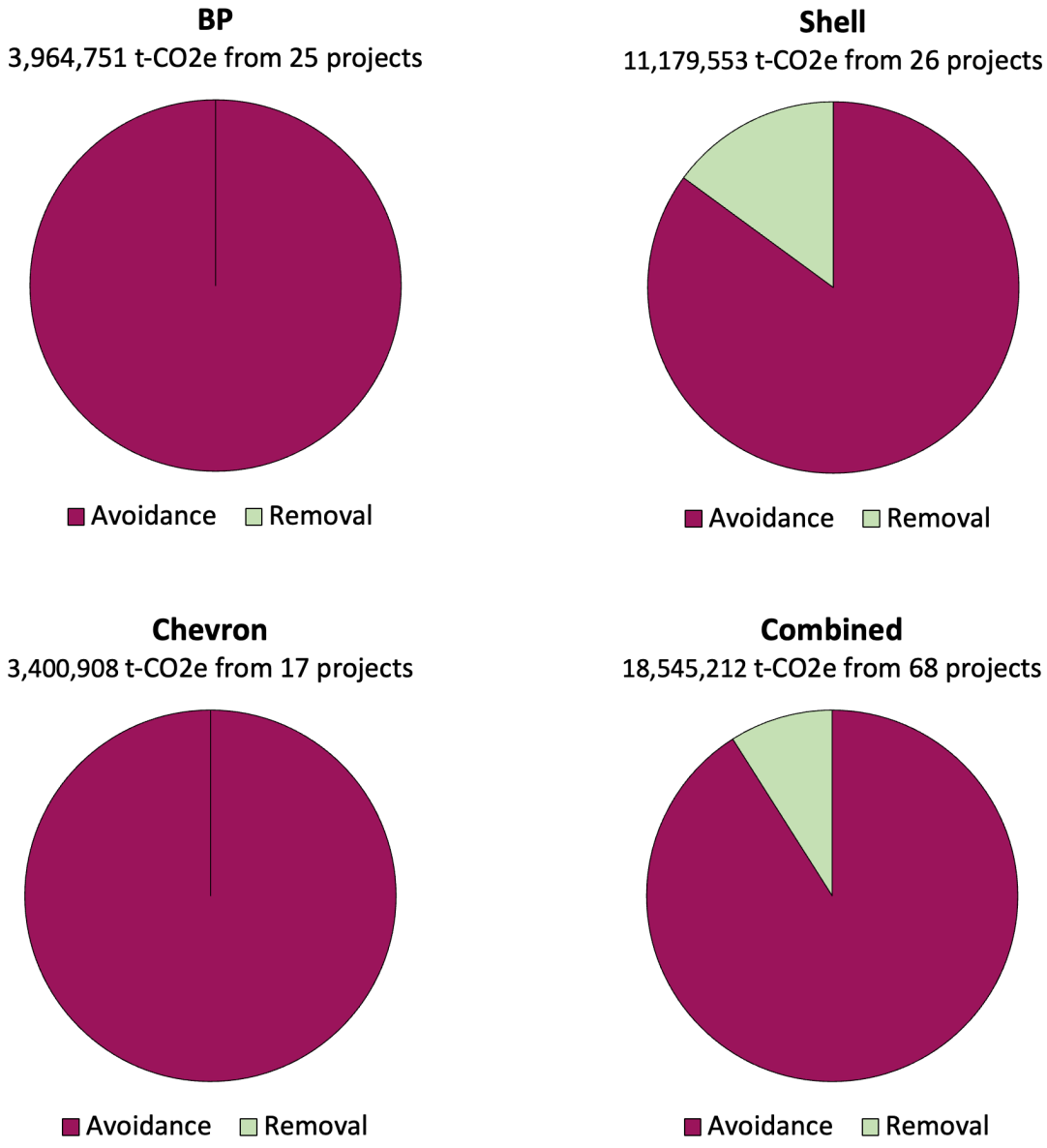

Figure 2 Type of offset projects used based on credit retirements (1 January 2020 to 31 December 2022)

Note: Amounts for BP and Shell include retirements reported in CDP questionnaire responses. See Research Design (Section 3.3) for explanation of coding of removal/avoidance for forest-conservation projects.

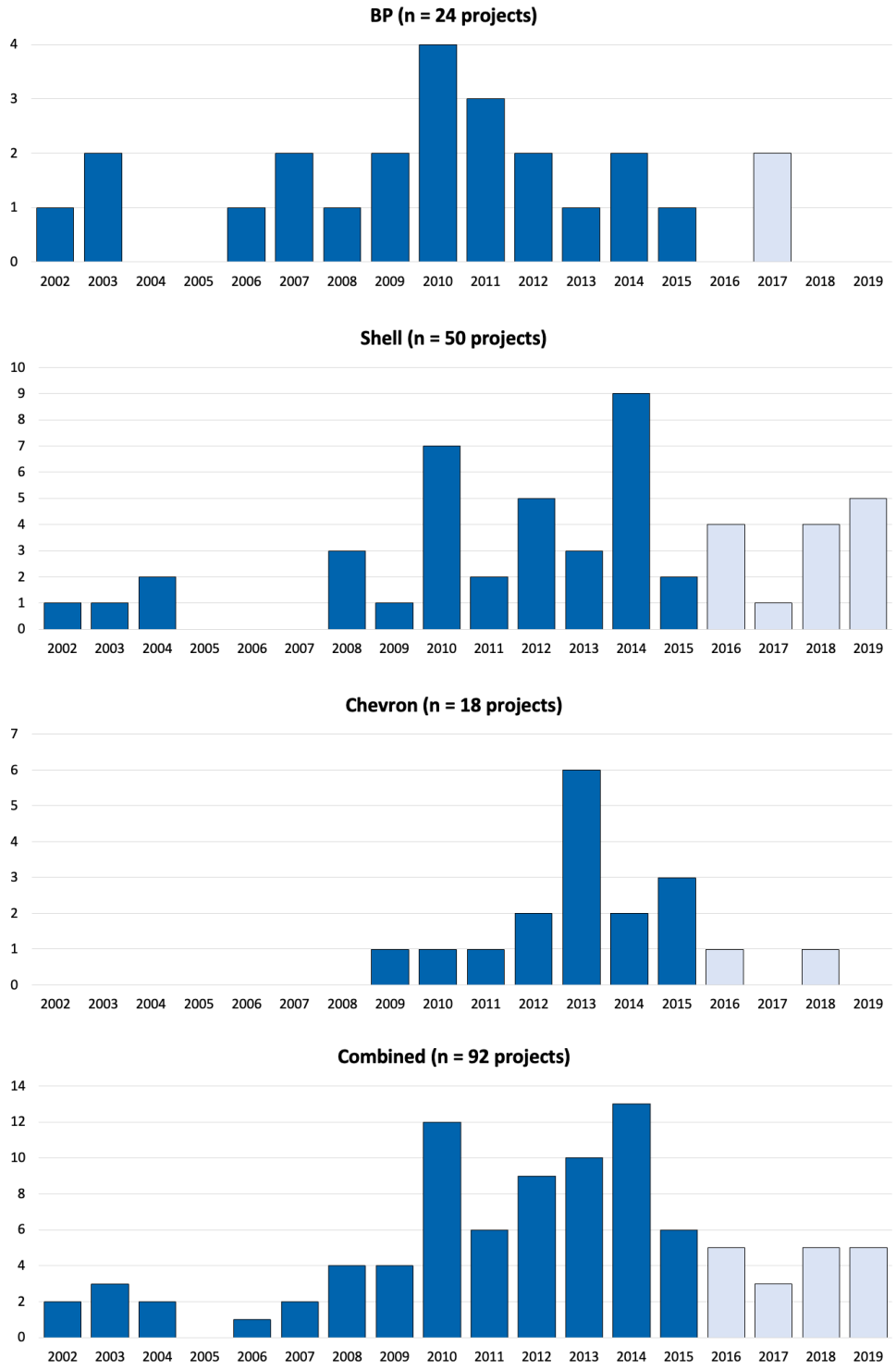

Figure 3 Age of offset projects based on start year of first crediting period

Note: The start year of the first crediting period captures the year that activities to reduce carbon emissions began (e.g. tree planting). Colours on bars reflect crediting period starts before and after 2016. This reflects the UN's CORSIA scheme for global aviation, which prohibits use of credits issued before January 2016. Figures exclude projects for which registries were unidentifiable.

4.3 Domains for offset hydrocarbons

We identified three principal domains where BP, Shell and Chevron are using offsets to claim carbon neutrality for conventional hydrocarbon products and services: LNG shipments, road transport and aviation services (**Table 5**).[12] Neutrality claims often cover the full fuel lifecycle, from extraction to combustion.

The strength of decarbonisation ambitions appears to influence the extent of engagement in each domain. While the more ambitious European majors BP and Shell have actively deployed products in each domain for several years, activities by the less ambitious American majors are limited. Chevron's activities only began in 2022, when it launched its first driver offset programme and cargo of 'carbon-neutral' LNG. ExxonMobil, meanwhile, having the least ambitious decarbonisation plans, is yet to enter the market. So again we exclude ExxonMobil from the following analyses.

Table 5 Core domains of offset hydrocarbons

	LNG shipments	Road transport	Aviation services
BP	✓	✓	✓
Shell	✓	✓	✓
Chevron	✓	✓	No evidence found
Exxon Mobil	No evidence found	No evidence found	No evidence found

LNG shipments

Seaborne deliveries of carbon-neutral LNG have become the flagship domain for using offsets to decarbonise regular hydrocarbon products. The full lifecycle emissions covering scope 1 to 3 of the LNG contained in a typical cargo amount to roughly 250,000 t-CO_2e (Cahill, 2022). By virtue of this volume, shipments of carbon-neutral LNG have constituted a major driver of credit retirements on the voluntary carbon market (Trove Research, 2022), and demand is expected to grow (Blantin and Mosis, 2021).

The first shipment of carbon-neutral LNG was delivered by Shell to Tokyo Gas in July 2019 (Shell, 2019b). Shell claimed that emissions across the entire LNG lifecycle were neutralised by avoidance offsets sourced from old forest-conservation projects in Indonesia (Pearce, 2021). This watershed transaction set a new trend in the global energy market,

[12] In addition to these areas, BP and Shell are marketing other forms of offset-bundled products such as lubricants, bitumen and even offsetting services for events (e.g. conferences). In defining three here, we highlight the most prominent domains of offset application.

triggering additional shipments by Shell and then by BP, Chevron and other majors (IEA, 2021a). Up to April 2022, 38 cases of offset-paired hydrocarbon transactions have been tracked (Trove Research, 2022). Though these include lubricants, ethylene and crude oil, LNG deals dominate, making up 24 (68%) shipments. The majority of cargoes have been delivered to energy suppliers like gas utilities in Asian countries such as Japan, China, South Korea, Taiwan and Singapore (Bose et al., 2021).

Shell is behind a large portion of carbon-offset LNG cargoes traded to date (Roach et al., 2022), delivering 11 in 2022 alone (Shell, 2023). BP and Chevron have also entered the market, but at a smaller scale. BP has announced only two deliveries so far, both in 2021, but it recently stated an intention to continue bundling offsets with energy products (BP, 2022d). Chevron only shipped its first cargo in late 2022, stating: 'we expect this offset-paired cargo to be the first of many' (2022d).

We identified from public announcements and registries 12 offset projects used by BP, Shell and Chevron between 1 January 2020 and 31 December 2022 to neutralise LNG cargoes (**Supplementary Information 1**). Mirroring the earlier analysis, we find that claims of carbon neutrality rely overwhelmingly on avoidance projects. That is, while BP, Shell and Chevron claim that offsets have neutralised the climate impact of producing, delivering and combusting LNG (Chevron, 2022d, Shell, 2021c, Shell, 2020a), 8 out of 12 offset projects used do not focus on atmospheric carbon removal. Meanwhile, the average start year for all crediting periods is 2014, with only four projects starting after January 2016 (the cut-off year for CORSIA). The tendency to use historical credits to neutralise LNG cargoes is particularly strong for Shell. This major has especially sourced credits from Katingan Peatland Restoration and Conservation Project in Indonesia and Cordillera Azul National Park REDD Project in Peru, amounting to 1.66 million t-CO_2e over the study period. Credits retired from the first project include vintage years dating back to 2010, while the latter project includes vintages from 2012 and 2008. Once again, this evidence shows that many claims of 'carbon-neutral' LNG rest shakily on credits issued a decade or more ago from avoidance activities that do nothing to remove contemporary emissions from the atmosphere.

The market of carbon-neutral LNG trades has grown rapidly since Shell's first trade in 2019, with many industry stakeholders predicting ongoing expansion in the coming years (Sahu and Yep, 2022, Peciccia, 2021). One analyst team even argued: 'we are witnessing the emergence of a new paradigm that will become a feature of the entire LNG industry in the

next five to ten years' (Roach et al., 2022). Despite such expectations, 2022 saw a considerable drop in trades (Stapczynski and Lee, 2023). Two reasons may underlie this. First, the Russian invasion of Ukraine has stressed global LNG supplies, prompting importing countries to prioritise energy security over carbon emissions (Kiernan, 2022). Second, the dubious claims about LNG's carbon neutrality have attracted heated criticism by media (Asada et al., 2022, Stapczynski et al., 2021), analysts (Trove Research, 2021a) and NGOs (Crook, 2021); the majors, facing risks of reputational damage, have an incentive to conceal new deliveries of carbon-neutral fuels, and offset projects paired with these. Thus, more offsetting deals for LNG trades may have occurred behind the scenes than were announced (Cahill, 2022, Hodgson, 2021), and this tendency may deepen into the future (Kiernan, 2022).

Road transport

BP, Shell and Chevron also harness offsets to reduce the emissions associated with fuel purchased by corporate fleet users or individual motorists. Each programme operates similarly. In the case of vehicle fleets, drivers receive a company fuel card, allowing them unrestricted use of that major's refuelling network. Emissions associated with each fuel purchase are then automatically offset with carbon credits sourced by that major. In the case of individual motorists, emissions from personal vehicle use can be offset through fuel cards or apps that surrender loyalty points or deduct a small surcharge[13] in exchange for carbon credits. Not only does this arrangement result in lower theoretical emissions for drivers, but offset fuel sales help the majors to make progress towards their carbon-intensity targets.

As with shipments of carbon-neutral hydrocarbons, the majors conjure the impression that contemporary carbon-reduction activities safely counterbalance emissions caused by vehicle use. BP and Shell even claim that their programmes allow carbon-neutral driving. Once again, however, credits used by Shell, Chevron and BP appear to rely heavily on aged avoidance projects that do not physically remove atmospheric carbon. For instance, Shell and Chevron have advertised their use of REDD projects[14] in Cambodia, Peru and Indonesia (Shell, N.D., Chevron, 2022e) for which credit issuing periods began around 15 years ago.

[13] For example, motorists offsetting a 30-litre fuel purchase in the Netherlands in 2019 could do so for only 0.30 euro.
[14] Specifically, Shell has stated use of the Cordillera Azul National Park in Peru and Katingan Peatland Restoration and Conservation Project in Indonesia. Chevron has stated use of the Rimba Raya Biodiversity Reserve in Indonesia and the Reduced Emissions from Deforestation and Degradation in Seima Protection Forest in Cambodia. Credit issuance periods for these projects began in 2010, 2010, 2009 and 2010 respectively.

BP has amassed the most experience with driver offset programmes. Its flagship Target Neutral initiative started in 2006 and serves fleet users in Europe and Canada (BP, 2022b). BP claims that 192,000 t-CO_2e were offset through the programme in 2021 and 8 million tonnes since 2006 (BP, 2022c). Shell has run its Drive Carbon Neutral programme since around 2019 (Shell, 2022b). This programme serves fleet customers in 21 countries and retail customers in nine (Shell, 2023). Its reputation has been considerably tarnished after a Dutch watchdog consistently called for its discontinuation (Hurst and Baazil, 2022), following assertions by NGOs and consumer groups that avoidance offsets cannot adequately compensate for motorist emissions (Reclame Fossiellvrij and Greenpeace, 2021). Shell has continued the programme regardless. It claims to have neutralised 49 million litres of fuel in 2021, amounting to 1% of total sales in markets offering offset programmes (Shell, 2021e).

Lastly, being the only American major to enter this market, Chevron began its driver offset programme in May 2022 via its Caltex brand, based in Singapore (Chevron, 2022e). The programme does not cover the totality of the fuel lifecycle, offsetting only 40%–60% of tailpipe emissions (Caltex, 2022).

Aviation

BP and Shell also harness offsets to offer carbon-neutral products for the aviation industry. These notably include: (1) wholesale packages of offset credits for airlines and customers to neutralise flight emissions; and (2) carbon-neutral aviation fuels, which bundle regular hydrocarbons with offsets. Both products tap into the aviation industry's burning need for drop-in decarbonisation solutions. With numerous airports and airlines across the world pledging to reach net-zero emissions by 2050, steep technological and cost barriers impede the achievement of such goals. Not only are biofuels costly and limited in supply, but breakthrough technologies like hydrogen and electric engines are still under development. Recognising this opportunity to profit from carbon-credit portfolios while reducing the theoretical climate footprint of aviation fuels, Shell and BP are actively championing offsetting as a decarbonisation tool for aviation (Shell and Deloitte, 2021, Shell, 2021a, Air BP, 2022).

Offset credits used by airlines and their passengers are issued from the regular project portfolios of BP and Shell. Shell's buyers include airlines such as Etihad and Jetex (Shell, 2021a), while BP supplies credits to Delta (BP, 2021a) and Qantas (BP, 2021b). Offsets

purchased by these airlines are used to meet carbon-reduction obligations under Europe's emissions trading scheme (EU-ETS) and CORSIA, while also offering carbon-conscious passengers a way to voluntarily offset individual flights.

Regarding the sale of carbon-neutral aviation fuel, evidence suggests this is currently an experimental, niche activity yet to mainstream across the aviation industry. BP entered this market first, around 2018, and since then has touted its supply of carbon-neutral fuels to several airports (BP, 2021d). Its airport customers, however, are small-scale, serving only specialty aviation markets. For instance, Teruel in Spain (BP, 2018) provides aircraft storage and maintenance, Cascais in Portugal serves regional light aircraft (BP, 2021d), and airports across Brazil support private jet travel. Shell, though it avidly promotes offset-paired hydrocarbons, entered the carbon-neutral aviation fuel market much later than BP. In early 2022, it made its inaugural delivery of carbon-neutral avgas to propellor-powered aircraft in the US, then expanded this service into Canada. Shell has signalled the intent to globally deploy its offset aviation fuels (Shell, 2022d).

This section has shown that coupling offsets with conventional hydrocarbons provides an attractive solution for decarbonisation goals in multiple sectors. Not only do offsets provide a cheaper and less disruptive solution than directly reducing emissions, but they also permit a conservative decarbonisation pathway. This allows majors to preserve their fossil-fuel operations while erasing associated emissions from their accounting legers. The 'carbon neutral' label also encourages continued demand for fossil-fuel products in an increasingly climate-constrained economy.

5. Discussion and conclusions

With oil majors claiming to be transitioning to clean energy and net-zero emissions, this study examined if the decarbonisation pathways of BP, Shell, Chevron and ExxonMobil entail a true shift away from fossil fuels. Our two-tiered investigation of net-zero strategies and offsetting tactics expands the research on the oil and gas sector's transition activities. Our novel dataset, built from company documents and registry data, has enabled the most in-depth analysis of offsetting activity to date, providing important evidence for policymakers, researchers and investors.

Our analysis of net-zero strategies found that no oil major's decarbonisation pathway reflects a fundamental business-model transformation aimed at shifting away from fossil fuels. First, only the European majors BP and Shell, hedging between a conservative and a transformative pathway, plan to reduce scope 3 emissions from all energy products. The American majors Chevron and ExxonMobil glaringly exclude scope 3 emissions from their net-zero goals, thereby omitting over 80% of lifecycle emissions (IEA, 2020) from decarbonisation ambitions. Second, no major has a concrete plan to decrease its overall supply of fossil fuels, inclusive of both production and sales. BP and Shell have omitted sales of third-party products from plans to reduce oil production, while Chevron and ExxonMobil are aiming to *increase* fossil-fuel production. Third, each major is using or plans to use offsets as a core instrument for reaching net-zero goals and for reducing the climate impact of conventional fossil-fuel products.

In aggregate, no major's net-zero strategy provides a blueprint to curb its supply of fossil fuels to the global energy market. To the contrary, our evidence reveals a common strategy built around continued fossil-fuel production and sales while claiming to reduce emissions via offsets and intensity-based targets. Our findings thus corroborate forecasts that absolute emissions from these majors may increase rather than decline up to 2030 (BP, 2020b, Liauw et al., 2022c). They also support observations that the majors' recent investments in renewable energy are additional to and not *displacing* fossil-fuel investments (Liauw et al., 2022a).

Our analysis of offsetting behaviour found contrasting degrees of engagement with offsetting activities and voluntary disclosure, particularly regarding credits retired from specific projects. Reflecting its unambitious transition strategy, ExxonMobil is yet to engage meaningfully with offsetting activities. Meanwhile, BP's ongoing unwillingness to disclose its credit retirements is conspicuous: though it claims to leverage over 20 registry-listed

offset projects, it leaves no trace of its retirements on public registries, unlike Shell and Chevron. We recognise that not every offset project in a major's portfolio will link to a named transaction in public registries, especially since offsets can be procured through intermediaries and self-developed projects or intended for selling to third parties. Yet the lack of consistent disclosure on registries regarding credit retirements makes it difficult for stakeholders to comprehensively track the volume, type and soundness of offsets used for decarbonisation activities.

Our analysis of available offset data, however, suggests that, taken together, their climate benefits are highly contestable. Although they share a narrative of using 'quality' offsets, most of BP's, Shell's and Chevron's projects do not support contemporary activities that physically remove atmospheric carbon. We found, concretely, that the bulk of offset projects rely on inferior avoidance activities. Data on credit retirements showed an even stronger preference for avoidance. For BP and Chevron, *all* retired credits since January 2020 are from projects where the primary function is emissions avoidance. For Shell, the share is 85%. Our analysis also revealed that most offset projects began issuing credits before 2016. Such projects are incompatible with the UN's CORSIA scheme that governs offsetting in the global aviation sector.

The strong reliance on historical projects and emissions avoidance revealed by our analysis indicates that the bulk of offsetting strategies by BP, Shell and Chevron fail to tackle the root cause of ongoing and future global heating – which requires physically *removing* carbon accumulated in the atmosphere. Even when theoretically 'offset', the production and combustion of fossil-fuel products from these majors will exacerbate climate change by adding heat-trapping GHGs to the atmosphere today. Our findings therefore cast doubt on the climate benefits generated by current net-zero strategies that rely on offsets, and on claims that emissions from hydrocarbons in LNG trade, road transport and aviation have been 'neutralised'.

Previous research has noted distinct behavioural differences between the European and American majors' climate ambitions, as well as factors that explain these (Green et al., 2021, Li et al., 2022, Vormedal et al., 2020, Kenner and Heede, 2021). Our research complements this understanding, and adds important nuances. The European majors, BP and Shell, were found to show more decarbonisation ambition than their American counterparts by including scope 3 emissions in the net-zero target. The European pair have also partially engaged with the need to reduce fossil-fuel production, although these plans

have been weakened recently, and conspicuously exclude the imperative to downscale sales of third-party-produced oil and gas. Their engagement with developing offset projects and bundling these with hydrocarbons like LNG cargoes also predates actions from Chevron and ExxonMobil. Yet our analysis of offsetting behaviour also revealed similarities, notably by highlighting the tendency of BP, Shell and Chevron to base claims of carbon neutrality and emissions compensation on aged removal projects. It is important for all stakeholders – not least investors and policymakers – that these similarities and differences in the offsetting behaviour of different majors be explored further in future research.

The trends highlighted by our analysis reflect a wider problem that exists beyond the oil and gas industry. Recent work finds that the net-zero strategies of companies in other industry sectors also tend to rely on offsets (Hans et al., 2022). Moreover, most credits retired on principal offset markets stem from avoidance projects (Shell and BCG, 2023) as tendencies to target cheap, old credits are increasing (Hong et al., 2022). Yet the entire voluntary carbon market is rife with quality issues (Rathi and White, 2022), since multiple scientific studies reveal a common trend of exaggerated or questionable climate benefits in offset projects (West et al., 2020, Cames et al., 2016). Numerous stakeholders are therefore contesting the ability of current offset markets to provide an effective solution for mitigating climate change (Rathi et al., 2022), calling for a shift towards projects that offer permanent carbon removal (Carton et al., 2022, Hong et al., 2022). Such technologies, however, are nascent and not yet available on major registries. Until their mainstreaming, net-zero strategies and the sale of neutralised hydrocarbon products that rely on offsets can be viewed as a greenwashing tactic, since in most cases the underpinning projects and credits do not reflect contemporary activities to remove atmospheric carbon.

As a cheap, drop-in solution, offsets are understandably very attractive for carbon-intensive industries. It is worrying that the Paris Agreement, along with many national governments and industries, is working to scale up the global offset market despite chronic and unresolved problems undermining its effectiveness as a climate solution. With BP, Shell and Chevron among the world's largest consumers of offsets, our study provides an empirical basis for calls to 'clean up' the voluntary carbon market and reduce reliance on offsets for net-zero strategies (Hans et al., 2022).

Finally, we invite other researchers to tackle new questions arising from our analysis. For instance, what factors influence the varying patterns of engagement with offsets as a decarbonisation tool and the choice of offset types across the majors? Additional

documentation and data from carbon markets may reveal some insights, but answering such questions satisfactorily might require interviewing stakeholders from each company and from the carbon market (Valiergue and Ehrenstein, 2022). Future research could examine a larger sample of oil and gas firms. We also see a need to continue monitoring the mainstreaming of offset-paired hydrocarbon products, particularly the types of offsets underpinning such products, and the influence of downstream buyers like gas utilities and airlines on the market's development.

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Supplementary Information 2 – Extra figures

For article:

Do all roads lead to Paris?
Comparing pathways to net-zero by BP, Shell, Chevron and ExxonMobil

Table SI 2-1 Example of voluntary credit retirement disclosure in a public registry

Vintage Start	Vintage End	ID	(Offset Project) Name	Country / Area	Project Type	(GHG Accounting) Methodology	Total Vintage Quantity	Quantity Issued (t-CO2e)	Retirement / Cancellation	Retirement Beneficiary	Retirement Reason	Retirement Details
01/01/2021	31/10/2021	2250	Carbon Removal Project ABC	Pakistan	Agriculture Forestry and Other Land Use	VM0033	1553947	4	04/11/2022	Company ABC	Environmental Benefit	To offset emissions for activity X

Note: This figure shows the example of data made publicly available through Verra's Voluntary Carbon Standard (VCS) registry. A company wishing to disclose its identity and reason for retiring credits can do so by entering the information in three coloured columns to the right.

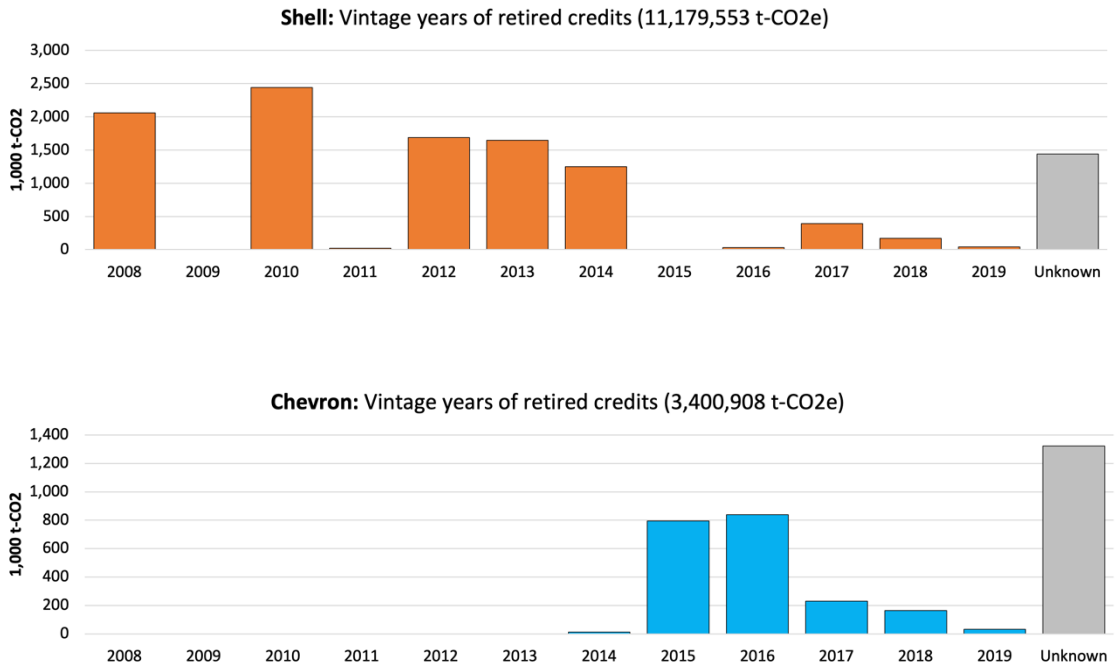

Figure SI 2-1 Age of offset credits based on vintage year

Note: Data for Shell include retirement volumes reported in CDP questionnaire responses