THE FUTURE FOR OIL & GAS MAJORS:

ACTIVITY IN THE LOW CARBON SPACE & MARKET REACTIONS

By

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ABSTRACT

This paper explores the influence of the green energy transition on oil and gas majors – namely, ExxonMobil, Chevron, Shell, BP, and TotalEnergies. Specifically, this study examines greenhouse gas emissions reductions strategies, investments in the low carbon space, and public market reactions to the energy transition. The global energy supply is forecasted to shift rapidly from hydrocarbons – oil, natural gas, and coal – to cleaner, lower-emission sources – hydrogen, bioenergy, solar, and wind – as economies target a net zero emission future. It is important to understand the strategies oil and gas majors are employing to drastically reduce their carbon footprint and position themselves within the energy transition. Using corporate sustainability reports and press releases, this paper analyzes empirical data relating to the energy transition, delving into the respective strategies of each oil and gas major. Additionally, this paper uses event studies to analyze abnormal returns on low carbon activities over time. The results indicate that emissions are starting to decline, but future net zero targets are inconsistent and relatively ineffective. Further, it finds that the U.S. majors lag behind their European counterparts, employing mitigative strategies whereas the European majors are building diversified portfolios of renewable energy technologies. Finally, it finds that activity in the low carbon space does not have a significantly accretive or dilutive effect on the market capitalization of each major.

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I. INTRODUCTION

The aim of this paper is to assess the impact of the green energy transition on the key players in the oil and natural gas industry. The central question at hand is bifurcated: *What actions are oil and gas majors taking to reduce emissions and prepare for a lower-carbon future, and how do public markets value these actions?* Given that oil and gas companies are primarily responsible for global greenhouse gas emissions and climate change, understanding their role within the energy transition is key to valuing their future operations and evaluating the feasibility of emissions reductions targets and net zero commitments.

The paper will focus on five of the largest and most influential players in the industry: ExxonMobil (or "Exxon"), Chevron, Shell, BP, and TotalEnergies (or "Total"). The rationale behind using investor-owned International Oil Companies (IOCs) rather than state-owned National Oil Companies (NOCs) is that data is more transparent, one can look at U.S. public market reactions, and NOCs have generally trailed IOCs in reacting to international climate-related agreements. Thus, IOCs are most representative of the future direction of the oil and gas industry. Additionally, given that two of the majors are headquartered in the U.S. (ExxonMobil, Chevron) and three are headquartered in Europe (Shell, BP, TotalEnergies), the paper will be able to show the disparity and potential lag between the U.S. and European oil and gas industry.

The study is split into six parts. The first section, relevant literature, provides an overview of contemporary research on the energy transition. The second section offers context on the history of the oil and gas industry, the possible shifts in future energy sources, and the types of low carbon technologies that oil and gas majors may adopt. The third, fourth, and fifth sections delve into the emissions data, low carbon activity, and public market reactions of ExxonMobil,

Chevron, Shell, BP, and TotalEnergies. Finally, the sixth and final section is a discussion on the aggregate results. This research uses firm-specific annual reports, sustainability reports, press releases, and emissions tracking data, as well as third party industry reports and CapIQ event study tools.

Analyzing each major's emissions data, the study finds that operating greenhouse gas emissions have consistently decreased since the 2016 Paris Agreement, indicating that companies are starting to act on their net zero commitments. However, emissions reductions targets are inconsistent across the industry and often overlook the impact of consumer use, so the majority of emissions are ignored and left to be a social cost. Forecasted carbon prices also indicate that the profitability of these companies could be heavily dependent on global climate policy. In order to reduce emissions, each company has invested, organically and inorganically, in low carbon technologies. This study finds that the U.S. majors have focused on mitigative technologies, while the European majors have diversified their low carbon portfolios and taken proactive steps towards becoming energy transition companies. Further, using event studies to determine the abnormal returns on energy transition press releases, this research suggests that low carbon activity does not necessarily dilute shareholders' equity. Compiling data from 2018 to 2023 for each of the five aforementioned majors, the event studies output slightly positive cumulative returns for the most part. Overall, this paper will contribute to the field of energy transition literature by helping investors and regulators understand the efforts and shortcomings of oil and gas companies as they transition to a lower-carbon future.

II. RELEVANT LITERATURE

Phases of the Energy Transition; Reactive & Proactive Responses

Since the inception of the Intergovernmental Panel on Climate Change (IPCC), climate science has developed considerably. Nowadays, evidence of anthropogenic climate change is amounting. Forecasts show increases in the frequency of severe weather events, rises in surface temperature, and rises in sea level. Modern research has established that giant oil and gas companies are primarily at fault for climate change. Heede's research found that 62% of global industrial emissions between 1751 and 2015 can be attributed to 100 currently operating hydrocarbon majors (Heede 2013). To limit global temperature rises to 1.5 degrees in coordination with IPCC recommendations, swift action must be taken, and oil majors will be at core of this transition.

A study by Kenner and Heede summarizes the responses of oil majors – focusing on BP, Shell, ExxonMobil, and Chevron – into five categories: Business as usual, incremental response, greater diversification, adapt to survive, and cling on and milk assets (Kenner and Heede 2021). The first phase can be categorized by responses before the establishment of the IPCC, as the majors suppressed internal findings about climate science. The second phase is categorized by the reactions to the IPCC, the Kyoto Protocol, and general government action to reduce greenhouse gas emissions. The four majors mentioned above responded by lobbying for climate change denial (with each major spending upwards of $100 million) and funding corporate political donations in the U.S. The European majors also onset small investments in the renewable space in the late 1990s, but the U.S. majors did not. ExxonMobil continued to publish its climate denial advertorials until 2004. Chevron temporarily entered the solar and wind space

but exited quickly. The third phase is generally where the four majors all stand now, as each has committed to net zero emissions by 2050 and ramped up its low carbon business. The European majors have ramped up their solar and wind businesses, invested in carbon capture and storage (CCS) technologies, and adapted EV charging points. The U.S. majors have been hesitant in the renewable space, but both ExxonMobil and Chevron have invested in CCS technologies. All four majors supported the Paris Agreement, acknowledged the risks of climate change, and joined the Oil & Gas Climate Initiative. Yet, they seem to be withholding from the fourth phase despite its inevitability. The fourth phase implies lower revenues and profits due to increased competition and lower market shares. Because of this, all four majors seem adamant on continuing their fossil fuel operations. Environmental expenditures as a per cent of total capital expenditures between 2010 and 2018 are 2.3%, 1.3%, 0.23%, and 0.22% for BP, Shell, Chevron, and ExxonMobil, respectively. These levels are far from what is needed to align with IPCC recommendations, which implies that each major wants to remain in the third phase for as long as possible.

Activity-based Analysis

Contemporary research often involves an activity-based approach to analyze the current role of oil majors in the energy transition. One study uses case studies on BP, Chevron, ExxonMobil, and Shell to analyze the mismatch between what majors are claiming to do versus actually doing (Li, Trencher, and Asuka 2022). This study assesses upstream capital expenditures, fossil fuel dependent earnings, average daily production volumes for oil and gas, proved oil and gas reserves, downstream petroleum sales, expenditures related to renewable energy and low carbon technologies. The study finds that each major's discourse does not align with its actions and investment behavior.

Another study analyzes Shell, ExxonMobil, Chevron, TotalEnergies, BP, ENI, Petrobras, and Equinor and scores their activities using relative values of investment in hydropower, solar, wind, biofuels, carbon capture, geothermal, and electric vehicle charging (Pickl 2019). The scoring system also includes metrics for low carbon capital allocation, a dedicated renewable energy team, and an established venture arm for low carbon investment. The study finds a significant discrepancy between U.S. and European oil majors. ExxonMobil ignored solar and wind investments in favor of fossil fuel projects, focusing instead on lowering emissions via carbon capture and storage (CCS) technologies and biofuel production. Chevron exited prior investments in renewables from the early 2000s and, like ExxonMobil, prioritized CCS technologies and other means of improved energy efficiency. On the other hand, BP, once one of the world's most prominent contributors to fossil fuel pollution, established a business unit entirely devoted to alternative energy sources while also adding a renewable-focused venture arm and investing organically (internal development) and inorganically (mergers and acquisitions) in a range of low carbon businesses. Shell has re-branded itself as an "energy transition company," increasing its renewable capital allocation and engaging in a series of inorganic investments within the space. Similarly, TotalEnergies has pushed to become a full range energy company, engaging in refining, chemicals, power generation, and renewables alongside their oil and gas business. Like BP and Shell, TotalEnergies has committed to increased capital allocation, both organic and inorganic, in the renewable space. In conclusion, a clear divide can be seen between the U.S. and European firms, as Pickl also plots proved oil reserves against renewable energy activity and shows the evident lag for U.S. oil majors.

A different study looks in depth at BP, Shell, TotalEnergies, Chevron, and ExxonMobil, five of the leading greenhouse gas emitters, and analyzes their historical and budgeted capital

expenditures (Merriman 2022). It finds that total capital expenditure budgets are set to increase substantially from 2021 to 2022. For the U.S. companies, the majority of Chevron's incremental expenditure comes from upstream fossil fuel production in the Permian basin, and ExxonMobil's hike is tied to expanding its refining and chemicals business. For the European companies, a higher (yet still miniscule when compared to future projections) portion of capital expenditures is devoted to renewable energy business units, but it is worth noting that incremental hikes are still seen in the upstream hydrocarbon businesses. The importance of this study is that budgeted capital expenditures in 2022 continue to show long-term inertia for hydrocarbons despite claims that the majors will reduce their fossil fuel operations. A similar study shows the severity of capital expenditure hikes, noting that the oil majors plan to hike up low carbon capital expenditure rates as high as 15% by 2025 (Alova 2022). Yet, rates have remained in the 0.2% to 2.3% range for the past decade. Despite many conditional promises, capital expenditure rates remain very low, and upstream hydrocarbon projects continue to develop.

Shareholder Sentiment

Another key metric of analysis is shareholder sentiment around climate-related actions. One study uses earnings calls of the oil majors between 2005 and 2019 to assess their stance on the energy transition (Green, Hadden, Hale, and Mahdavi 2021). It uses key word sentiment analysis to show whether firms have accepted climate science, national climate policy, carbon pricing, and the possibility of an energy system not hinged on fossil fuels. The dataset uses BP, TotalEnergies, Chevron, ConocoPhillips, ExxonMobil, ENI, Repsol, Equinor, Shell, and Occidental, and the earnings indicators relate to {end fossil fuels, climate science, carbon price, international agreements, national laws, and CCS}. It finds Shell, Equinor, and BP to be at the

top of the pro-climate index, while Chevron, ConocoPhillips, and ENI are at the bottom. Surprisingly, ExxonMobil lies above TotalEnergies on the index.

A different study determines the impact of climate policy on U.S. listed oil and gas firms, using weekday and weekly cumulative average abnormal returns (CAAR) (Rainey, Gehricke, Roberts, and Zhang 2021). Four major events are evaluated: the Paris Agreement (December 2, 2015), the ratification of the Paris Agreement in the U.S. and China (September 3, 2016), the election of Donald Trump (November 8, 2016), and the U.S. withdrawal from the Paris Agreement (June 1, 2017). The Paris Agreement led to significant negative returns, with the smallest impact behind -7.58% CAAR on the first weekday. The ratification yielded no significant CAAR. The election of Trump produced negative CAARs, which was surprising yet can be attributed to his support of U.S. shale, an industry dominated by small and private players. Finally, the withdrawal from the Paris Agreement was met with negative returns due U.S. public perception of the treaty and Trump's focus on local production.

Qualitative Assessment of Theories on Transition

In the well-known paper "Fossil Capital: The Rise of Steam Power and the Roots of Global Warming" (Malm 2016), the author claims that it is profit, not price, that drives energy transitions. He uses nineteenth century England as his primary example, delving into the transition from the waterwheel to the steam engine and finally to coal. He shows that price alone did not drive this transition (for example, water was not scarce and was cheaper than steam). But rather, investment profiles drove the transition, as capital consolidation, labor control, and portability made fossil fuels a more attractive investment than water or steam.

Another study builds off Malm's paper by detailing the contemporary renewable energy investment space. Christophers claims that, between 2010 and 2020, investment in renewables and other low carbon technologies rose sharply due to government subsidies and tariffs that alleviated the burden of the high barrier fixed cost of renewable projects (2021). Yet, significant government pushback has occurred since 2020, making renewable projects a low margin, high risk investment. Still, the European oil majors have pledged to ramp up investment in the low carbon space while simultaneously divesting from hydrocarbons, despite lower expected returns. The study also finds flaws in the claims of European oil majors. Their pledges hinge on carbon capture and storage technologies that remain unproven, and their future projections rely on highly sensitive assumptions about carbon prices. To this day, fossil fuel investments still promise a higher return profile than renewable projects, which is driving the mismatch between company pledges and investments.

Finally, a study claims that there are three key aspects to a successful transition: organizational steering, technical leverage, and the power of synergies (Abraham-Dukuma 2021). The Danish oil and gas company DONG-Ørsted is used as a reference for a successful transition from being a hydrocarbon company to a green energy company. This paper also finds that, for IPCC recommendations to be met, fossil fuels will be left in the ground. That is, oil and gas companies will have to effectively faze out fossil fuels rather than balancing their business models.

III. BACKGROUND ON BIG OIL & RENEWABLE ENERGY

A Brief History of Big Oil

Hydrocarbons can be grouped into three general categories. Conventional oil, such as crude oil, condensate, and natural gas liquids, is the easiest to access, accounting for the vast majority of global liquid fuels. Unconventional oil, such as extra heavy oil, oil shale, oil sands, and tight oil, is less accessible and thus accounts for a smaller market share. Unconventional liquids, such as coal-to-liquids, gas-to-liquids, and biofuels, are synthetically produced and have risen in market share in the past decade. Coal will not be relevant to this study, as the industry faces an irreversible decline due to high intrinsic costs and public perceptions (Grasso 2018).

Oil is a ubiquitous global product and input, used not only as the primary source for fuel and energy but also for computers, medicine, and a vast array of other products. The oil economy began with the inception of Rockefeller's Standard Oil Company in the late nineteenth century, with its European rival Shell following close behind. By the 1970s, a handful of IOCs dominated the industry. Yet, in the past thirty years, NOCs, such as Chinese PetroChina, Russian Gazprom, National Iranian Oil, and Saudi Arabian Aramco, have increased their market share dramatically. This shift in market share from IOCs to NOCs can be attributed to politics and the United Nations granting national sovereignty over natural resources. As of 2017, NOCs owned 90% of oil reserves, as opposed to 1% in 1970 (Grasso 2018).

The oil industry has extremely high barriers to entry and fixed capital costs. The process of extracting carbon atoms from hydrocarbon molecules that originate from ancient marine and land organisms buried in sand and rock requires extremely advanced technologies. For these reasons, the industry is very concentrated, and the firms that dominate the industry are likely to

be vertically integrated – their businesses cover exploring, producing, refining, and distributing oil and gas across the globe. The industry is also massive and immensely profitable, with total oil and gas revenues reaching $2 billion globally in 2017 (Grasso 2018).

It wasn't until the late 1980s that climate science was publicized. The Intergovernmental Panel on Climate Change (IPCC) published its first report correlating greenhouse gas emissions to climate change in 1990. The initial response of IOCs was extremely negative, as the majority of IOCs joined the Global Climate Coalition to fund climate science denial. In the late 1990s, BP and Shell left the coalition, accepted climate science, and even contributed small capital outlays in the solar and wind business. This created a divide with their American counterparts, as firms such as ExxonMobil and Chevron continued to deny climate science and greenhouse gas control while lobbying against climate policy. ExxonMobil took a long and ambiguous path towards accepting climate science, as the firm finally disclosed its acceptance of the risks of climate change to shareholders and halted its funding of climate change denial in 2007. Yet, ExxonMobil's first annual report that acknowledged climate change was in 2014. The majority of IOCs had established their belief in climate science by 2015, yet many still remained involved in trade associations that denied and lobbied against climate change and policy (Grasso 2018).

The Paris Agreement, an international treaty on climate change that motivated net zero commitments, was adopted in 2015. IOCs generally supported the agreement, as even ExxonMobil, a historically stout denier of climate science, released a statement in concurrence with the treaty. However, the words of IOCs differed vastly from concrete actions. In ExxonMobil's case, the disparity between words and action can be seen in the Supran and Oreskes testimony. NOCs, which had historically trailed behind IOCs in their beliefs of climate science, were also involved in the treaty, but organizations like OPEC had fought against

climate-related issues to no end. The treaty yielded two primary courses of action for oil and gas majors: invest in renewables or modify their business models (Grasso 2018).

IEA Net Zero Scenario & the Future Outlook for Energy

In May of 2021, the International Energy Agency (IEA) published its *Net Zero by 2050* report, stating that the purpose of achieving net zero greenhouse gas emissions by 2050 is to minimize the rise in global temperatures to 1.5 °C (IEA 2021c, 3). The IEA's *World Energy Outlook 2022* provides an update for what the future share of energy supply might look like under its net zero scenario (IEA 2022k, 128).

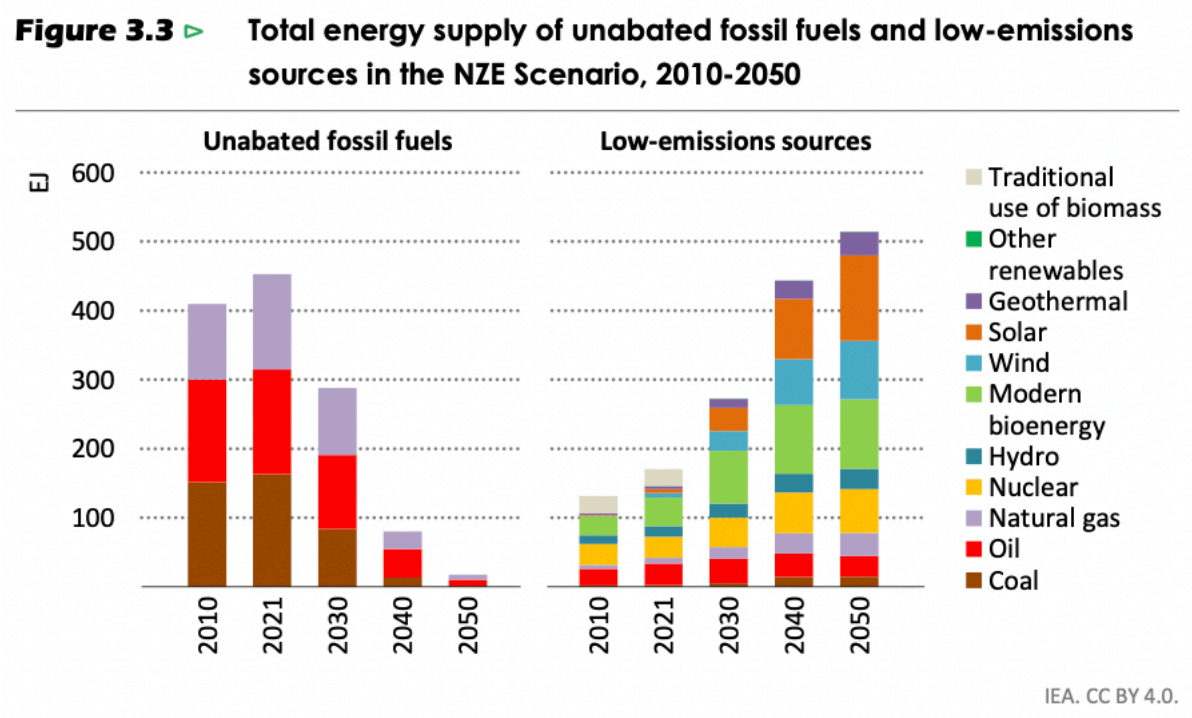

Figure 3.1.1: Shares of total energy supply from 2010 to 2050, forecasted in the IEA's *World Energy Outlook 2022* report.

This figure exhibits a steep decline in oil, natural gas, and coal supply between 2021 and 2050. On the other hand, renewable energy sources – notably solar, wind, and bioenergy – are forecasted to grow rapidly in this timeframe. This shift is extremely ambitious compared to current levels of capacity for low carbon technologies; however, it offers a picture of what global energy supply may look like if corporate and public sector net zero initiatives are successfully met.

A Brief Overview of Low Carbon Alternatives

The majority of companies in the oil and gas industry have committed to achieving net zero greenhouse gas emissions by 2050, whether it be measured by operated assets, equity and operated assets, or all emissions including consumer use. In order to reduce emissions and position themselves within the energy transition, oil and gas majors have engaged in activities in the low carbon space. The different low carbon technologies are described below.

Carbon Capture, Utilization, and Storage: Also referred to as CCUS or CCS, carbon capture, utilization, and storage is a low carbon technology that enables the capture of carbon dioxide from point sources, namely being power generation or industrial facilities. The carbon dioxide is either used on-site, compressed and transported to be used in a range of other activities, or injected into deep geological formations permanently. At the end of 2022, the global capacity for carbon dioxide capture projects stood at about 40 Mta (million metric tons of carbon dioxide annually), and under the IEA Net Zero Scenario this figure will have to increase to approximately 1,250 Mta (IEA 2022c). Thus, development of carbon capture facilities will have to progress rapidly to meet global net zero goals.

Hydrogen: Hydrogen is a clean energy source that generates electrical power in a fuel cell. Its only byproduct is water vapor, making it key for emissions reductions (U.S. Department of Energy). There are three main types of hydrogen in terms of the energy transition: grey, blue, and green. Grey hydrogen is currently the most common. It is produced industrially from natural gas, a very energy-intensive process. Blue hydrogen is essentially a cleaner version of grey hydrogen; the carbon emissions from production are captured and utilized or stored. Green hydrogen is the cleanest version, as it is generated using renewable energy sources – the electrolysis of water – and does not emit carbon emissions when produced (IEA 2019). Hydrogen is particularly important in the energy transition because of its fuel uses, enabling emissions reductions in sectors that are particularly difficult to decarbonize, such as steel manufacturing, chemical production, road transport and shipping, and aviation. Hydrogen also plays a significant role in the power sector due its uses in gas-fired power plants and stationary fuel cells. Despite hydrogen's current cost barrier, it has the potential to be widely adopted and could enable up to 60 Gt (gigatons) of emissions reductions by 2050. According to the IEA, hydrogen production will have to increase from approximately 100 Mt (million metric tons) in 2020 to over 500 Mt in 2050, predominantly comprised of growth in green and blue hydrogen (IEA 2021a, 19-20).

Biofuels: Bioenergy is a near zero-emission fuel that uses biomass, the organic material that makes up plants, to produce energy. The carbon from the biomass is simply released back into the atmosphere via combustion, making the energy production circular. Bioenergy currently comprises over fifty per cent of renewable energy sources and is projected to continue displacing fossil fuels (IEA 2022a). Looking more in depth into biofuels, ethanol (from corn, sugarcane, or other plant materials), biodiesel (from "Fatty Acid Methyl Ester"), and renewable diesel (from

"Hydrotreated Vegetable Oil") have all experienced increases in global demand over the past few years. Biofuels present a low carbon alternative for light-duty vehicles, and with advances in technology they could be used to fuel heavy-duty trucks, ships, and planes in the future. In aggregate, biofuels represented 3.6% of global transport energy demand in 2021, and to reach the 2030 and 2050 IEA Net Zero Scenario this figure will have to grow over fifteen per cent per year (IEA 2022b).

Solar: Solar energy is a renewable energy source that converts sunlight into usable energy. Solar technologies revolve around solar photovoltaics (PVs), thermal electricity, and heating and cooling. Solar PV generation surpassed 1000 TWh (Terawatt-hours) in 2021 and is projected to exceed coal's installed power capacity by 2027. With commodity prices proving to be extremely volatile over the past few years, utility-scale solar PV and distributed (residential, commercial and industrial) solar PV have become cost efficient electricity alternatives for a majority of countries. To meet the IEA Net Zero goals, solar PV's annual generation growth must increase to about twenty-five per cent between 2022 and 2030, driven by global policy and public and private investment (IEA 2022i).

Wind: Wind energy refers to the use of wind to generate electricity from turbines. Wind energy is the second leading renewable energy source behind hydropower, nearing 2000 TWh. Onshore wind systems are a developed technology that currently dominate the share of wind capacity, while offshore wind farms are still in their early stages of development. In order to follow the IEA's Net Zero Scenario, wind energy must increase to about 8000 TWh by 2050, and this growth will likely be driven by increased productivity, lowered costs, and global policy support (IEA 2022j).

Nuclear: Nuclear power is a well established large-scale low emissions energy source that will play an important role in the pathway to net zero. The basis of nuclear energy is nuclear fission, the process of splitting certain atoms and generating steam to produce electricity. In contrast, nuclear fusion, a far less proven technology, usually involves uniting two hydrogen isotopes to generate energy (Duke Energy Corporation 2021). Global nuclear capacity is forecasted to double from 413 GW in 2022 (gigawatts) to 812 GW in 2050 under the IEA Net Zero Scenario. However, oil and gas majors have generally avoided investment in this space due to market uncertainty, high upfront costs, public perception, and residual waste (IEA 2022h, 8-16).

Hydropower: Hydropower is the largest global source of clean and flexible electricity generation. It is a mature technology that involves harnessing the flow of water to generate electricity. Its capacity was 4327 TWh in 2022, and under IEA's Net Zero Scenario it should increase to nearly 6000 TWh by 2050. Growth is expected to stagnate in the future, with forecasts indicating its renewable market share will decline due to the wider adoption of solar and wind energy (IEA 2022g). Hydropower is mainly driven by public sector investment, and oil and gas majors have been relatively hesitant to enter the space because of the limited investment opportunities and the aging technology behind it (IEA 2021b).

Geothermal: Geothermal energy is a renewable energy source that generally involves drilling deep into Earth's core and using hot water for heating or electricity. Unlike solar and wind, geothermal energy is not intermittent; however, deep drilling can be costly and risky (Robbins 2020). It is still in its early stage of technological development, representing only 92 TWh of the global renewable energy capacity in 2019. However, its benefits could allow it to

displace fossil fuels in the future, and some oil and gas majors have invested in geothermal research and deployment in recent years (IEA 2022e).

Electric Vehicles and Charge Points: Electric vehicles are particularly important for oil and gas majors that are aiming to reduce Scope 3 emissions. Battery development and convenience sites with electric vehicle charge points have become increasingly attractive investments for oil and gas majors, especially those based in Europe. In 2021, global electric vehicles displaced approximately 0.3 Mb/d (million barrels per day) of oil, and this figure is targeted to grow to 7 Mb/d by 2030 under IEA's Net Zero Scenario. This growth will likely be driven by government support of vehicle electrification, increased electric vehicle investment, and increased deployment of public charge points (IEA 2022d).

IV. EMISSIONS ANALYSIS

Recent Trends in Greenhouse Gas Emissions

Tracking data since 2016 (after the Paris Agreement), one can see a negative trend in greenhouse gas emissions among the oil and gas majors, as each of the five companies has since publicly commited to net zero by 2050 and established a low carbon business unit. Shown below are a few key definitions.

Scope 1: direct emissions from assets operated or controlled by the company.

Scope 2: indirect emissions associated with the energy that is needed to run operations.

Scope 3: emissions that are not produced by the company but rather are produced indirectly across the value chain of the products, such as emissions resulting from the use and disposal of products (National Grid plc 2023)

Operating Emissions: calculated as one hundred per cent of emissions from assets, companies, or joint ventures where the company has operational control. This does not include emissions from projects where the company has stake but not control.

Equity Emissions: calculated as equity share of emissions from all assets, companies, and joint ventures (Ford 2021)

The majority of the data presented in this project will be in terms of operating emissions, unless otherwise specified, in order to normalize results across all five companies. Shown below is the historical operating emissions data for the five companies, followed by a graphical representation of the data and the rate of decline.

Company	2016	2017	2018	2019	2020	2021	2022
Exxon	117	113	115	109	102	102	99
Chevron	68	69	70	64	57	59	54
Shell	81	85	82	80	71	68	58
BP	58	57	54	54	46	36	32
Total	45	42	44	44	41	37	40

Figure 4.1.1: Data set of Scope 1 and 2 operating emissions from 2016 through 2022, measured in CO2e (carbon dioxide and equivalents). The emissions figures are provided publicly by each company with respect to the Task Force on Climate-related Financial Disclosures (TCFD) framework (ExxonMobil Corporation 2023a, 4; Chevron Corporation 2023, 62-63, 2021b, 50-51; Shell plc 2023b, 2018; BP plc 2023b, 22, 2020, 24, 2018b, 14; TotalEnergies SE 2023b, 377, 2020, 232).

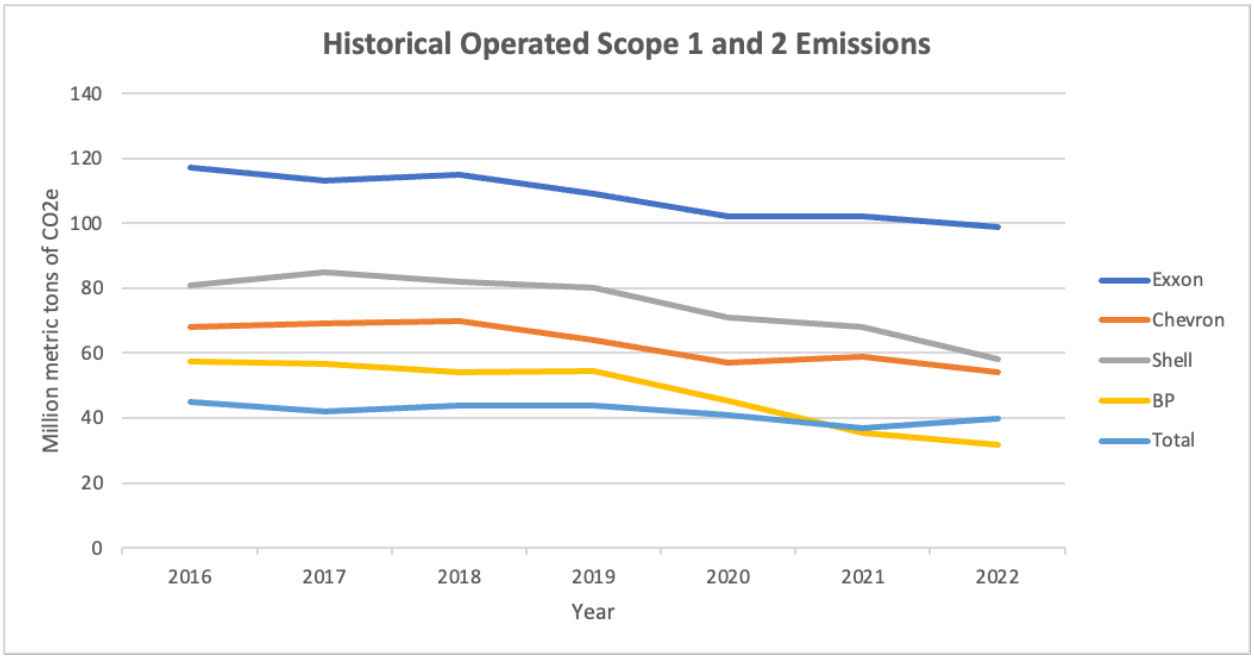

Figure 4.1.2: Graphical representation of the data shown in the prior figure

Company	CAGR
Exxon	-2.75%
Chevron	-3.77%
Shell	-5.41%
BP	-9.38%
Total	-1.94%

Figure 4.1.3: Calculations of the compounded annual growth rate (CAGR) of Scope 1 and 2 operated emissions for each company.

Using the *Business as Usual* assumption, the average emissions reductions per year over this timeframe can be used as a proxy to find the year in which operating Scope 1 and 2 emissions are netted to zero. This assumption implies each company will reduce its emissions a constant rate until each net zero commitment is realized, which is not feasible but offers a rough estimate of how realistic these net zero ambitions really are. This assumption also negates Scope 3 emissions, which, if included in net zero commitments, will present a significant hurdle for oil and gas majors.

Company	Average Reductions per Year	Years Until Operating Emissions = 0	Net Zero Year
Exxon	3.0	33.0	2055
Chevron	2.3	23.1	2046
Shell	3.8	15.1	2038
BP	4.3	7.4	2030
Total	0.8	48.0	2070

Figure 4.1.4: This chart depicts the year in which operating emissions equal zero using average emissions reductions between 2016 and 2022 as a proxy.

The results indicate that, since 2016, these five companies have taken measures to reduce operating greenhouse gas emissions. Four of the five majors are projected to reach net zero operating emissions before 2050 if they continue to reduce emissions at the same pace. TotalEnergies has the slowest pace of emissions reductions since 2016, but the company has deployed extensive capital into its low carbon business and should realize greater reductions in the coming years.

Emissions Reductions Targets

The five companies being analyzed use different reporting metrics to assess their net zero transition. The differences between each commitment are outlined below.

ExxonMobil: As of the latest *Advancing Climate Solutions* report in 2023, ExxonMobil aims to achieve net zero Scope 1 and 2 greenhouse gas emissions by 2050 across all operated assets. By 2030, the company targets net zero Scope 1 and 2 emissions in its Permian unconventional operated assets and reductions in upstream intensity, methane emissions, and flaring. To reduce greenhouse gas emissions and intensity, the company aims to increase deployment of carbon capture, replace natural gas with blue hydrogen in its manufacturing operations, replace unabated coal with liquified natural gas, displace crude oil with renewable sources for fuel, and use lower-emission sources to electrify operations (Exxon Mobil Corporation 2023b).

Chevron: As of October 11, 2021, Chevron set a net zero aspiration for all equity upstream Scope 1 and 2 greenhouse gas emissions by 2050 (Chevron Corporation 2021a). The company also reports its portfolio carbon intensity (PCI), which captures the full value chain of its emissions (Scope 1, 2 and 3). To achieve net zero upstream emissions, Chevron set 2030 targets that revolve around adopting renewable fuels, hydrogen solutions, carbon capture and storage, and carbon offsets into its operations (Chevron Corporation 2023).

Shell: In 2020, Shell announced its target to become a net zero emissions energy business by 2050. The majority of emissions reductions are forecasted to come from operated assets, as the company forecasts a fifty per cent reduction in absolute Scope 1 and 2 emissions from operations by 2030. To achieve these targets, the company has committed to reducing net carbon intensity and investing in low carbon energy solutions. The company has recently expanded its

electric vehicle network and renewable power platform while also developing green hydrogen and growing its biofuels portfolio, positioning itself within the energy transition (Shell plc 2023a).

BP: In 2020, BP announced its ambition to become a net zero emissions energy business by 2050. The company's net zero goal has since been split into five aims. First, the company aims to be net zero by 2050 across all operations, relating to Scope 1 and 2 emissions. This aim does not include equity emissions outside of BP's operational control. Second, BP aims to be net zero by 2050 on a Scope 3 basis, referring to consumer use of the carbon from its upstream oil and gas production. The third, fourth, and fifth aims relate to carbon intensity, methane emissions, and increase low carbon investment, respectively. The key low carbon investments that BP identifies are biofuels, electric vehicles and convenience sites, renewable power, and hydrogen (BP plc 2023).

TotalEnergies: In 2021, TotalEnergies defined its strategy for achieving sustainable development and achieving net zero greenhouse gas emissions by 2050. The company's commitment includes industrial operations (Scope 1 and 2) on a equity basis, as well as consumer use of products (Scope 3). By 2050, the company envisions fifty per cent of its energy production will be renewable electricity and twenty-five per cent will come from biogas, hydrogen, and synthetic liquid fuels, drastically shifting its energy mix from hydrocarbons to low carbon solutions. Further, to achieve net zero, the company will offset residual emissions with natural carbon sinks (TotalEnergies 2022, 12-13).

Summary Analysis: As shown in the chart below, each company's net zero commitment varies significantly in its coverage of Scope 1, 2 and 3 emissions. Without operational control, equity emissions outside of the operational boundary present a challenge for oil and gas majors,

and ExxonMobil and BP do not include such emissions in their commitments. Since 2016, all five companies have disclosed estimates of their Scope 3 emissions, but a common critique of oil and gas majors' net zero commitments is that they have failed to integrate Scope 3 emissions into their emissions reductions strategies. Scope 3 emissions are particularly difficult to estimate, as they quantify the full range of indirect emissions of energy products used by consumers. ExxonMobil, Chevron, and Shell have yet to include Scope 3 emissions in their net zero strategies, claiming that the estimates are not accurate and that mitigating these emissions would severely impair their business models and profitability (Hanley 2023). However, Scope 3 emissions represent an overwhelming majority of total greenhouse gas emissions for these three companies, leading many to question the real impact of their net zero commitments. In 2021, for example, ExxonMobil's Scope 3 emissions from the use of crude oil and natural gas production were estimated to be 530 Mt (Exxon Mobil Corporation 2023b, 92), Chevron's Scope 3 operating emissions according to the production method were approximately 621 Mt (Chevron Corporation 2023, 63), and Shell's total Scope 3 emissions on an equity basis (operating not disclosed) were estimated at 1,299 Mt (Shell plc 2022a). These figures are difficult to normalize across all five companies because the reporting metrics are not standardized.

Net Zero by 2050 coverage	Exxon	Chevron	Shell	BP	Total
Scope 1 and 2 – Operated Assets:					
Upstream	✓	✓	✓	✓	✓
Downstream	✓		✓	✓	✓
Chemical	✓		✓	✓	✓
Scope 1 and 2 – Non-operated Assets:					
Upstream		✓	✓		✓
Downstream			✓		✓
Chemical			✓		✓
Scope 3:					
Disclosed?	✓	✓	✓	✓	✓
Part of NZE?				✓	✓

Figure 4.1.5: Chart of emissions covered under each company's net zero by 2050 plan.

Carbon Prices and Cost of Emissions

With net zero commitments in place, oil and gas majors could suffer financial losses due to their future carbon emissions. One way to analyze these costs is to forecast market-based carbon offset prices and carbon taxes. In May of 2022, there were thirty-two emissions trading systems and thirty-eight carbon taxes on fuels, covering over forty countries (IEA 2022f, 20). There are significant differences across regions with respect to the implementation of carbon prices. The global weighted-average carbon price was estimated to be $15/t in 2022. Additionally, approximately twenty-three per cent of global greenhouse gas emissions were covered under a direct carbon pricing regime in 2022, nearly doubling since 2020 (Systems Change Lab 2023). Given that all regional markets have access to carbon offsets, this analysis will assume that all carbon prices converge, thus normalizing the cost forecasts for all five companies. Using the IEA Net Zero Scenario assumptions for advanced economies, carbon prices, measured in real 2021 U.S. dollars, will rise rapidly in the next three decades, reaching $140/t in 2030, $205/t in 2040, and $250/t in 2050 (IEA 2022f, 20).

Key assumptions in analysis: This analysis only assesses carbon prices on operating emissions, emitting the costs of non-operated asset emissions and Scope 3 emissions. It assumes that each company's emissions will decline to zero in 2050 at a constant rate based on the company's disclosed 2022 operating Scope 1 and 2 emissions. Carbon prices are assumed to converge to the same value across all regions, and the forecasts are based on IEA figures for advanced economies with net zero emissions pledges. Given that the IEA only assesses carbon prices at the end of the next three decades, the yearly prices are tapered at constant rates within each decade. The purpose of this analysis is to evaluate the downside risk from increased carbon prices and integrated global climate policy, so each company is assumed to purchase market-

based carbon offsets to net out its operating emissions every single year. The following five charts forecast the scenarios as outlined.

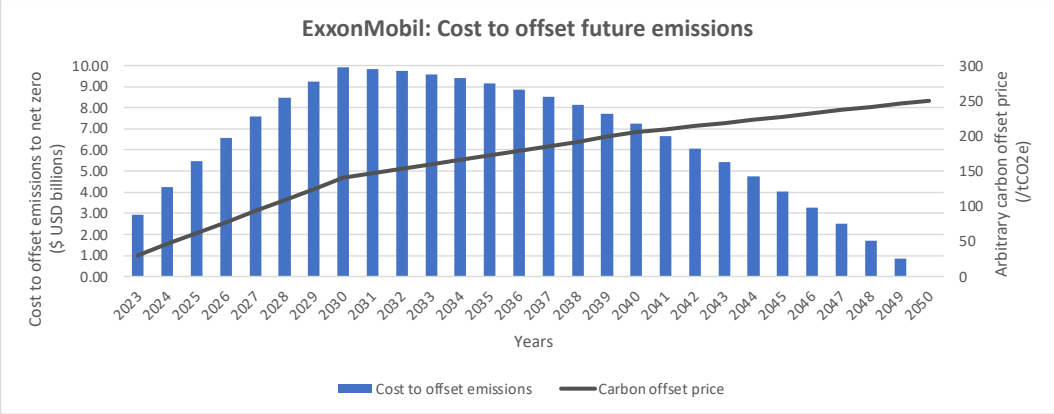

Figure 4.1.6: Chart of costs to offset emissions plotted against forecasted carbon prices for ExxonMobil, 2023 through 2050.

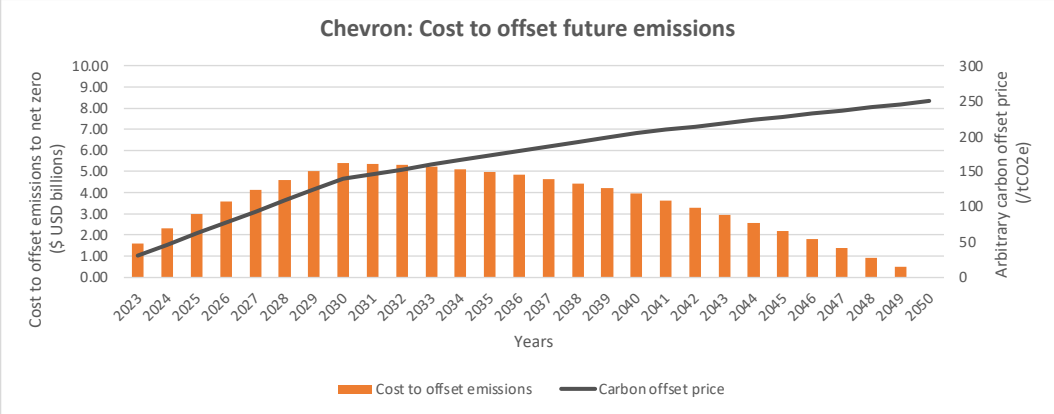

Figure 4.1.7: Chart of costs to offset emissions plotted against forecasted carbon prices for Chevron, 2023 through 2050.

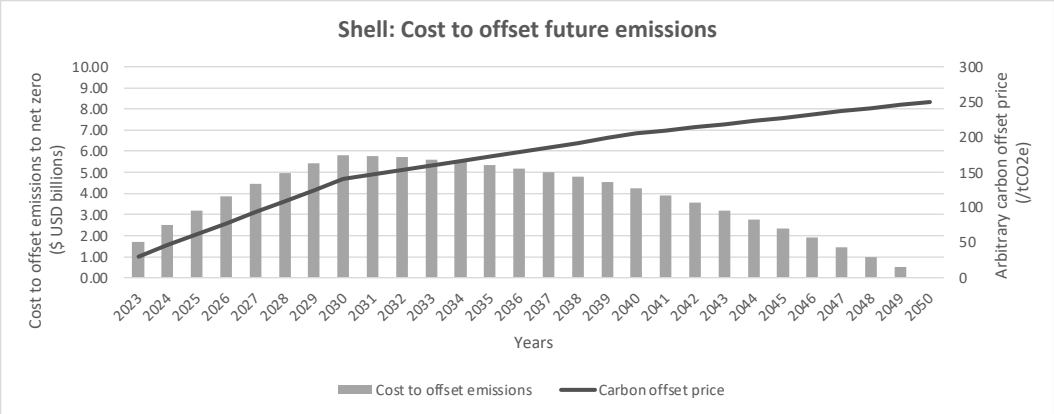

Figure 4.1.8: Chart of costs to offset emissions plotted against forecasted carbon prices for Shell, 2023 through 2050.

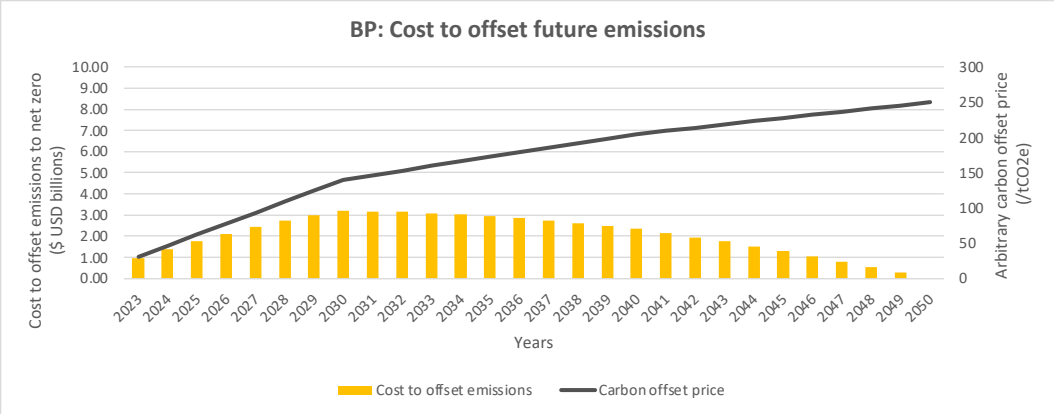

Figure 4.1.9: Chart of costs to offset emissions plotted against forecasted carbon prices for BP, 2023 through 2050.

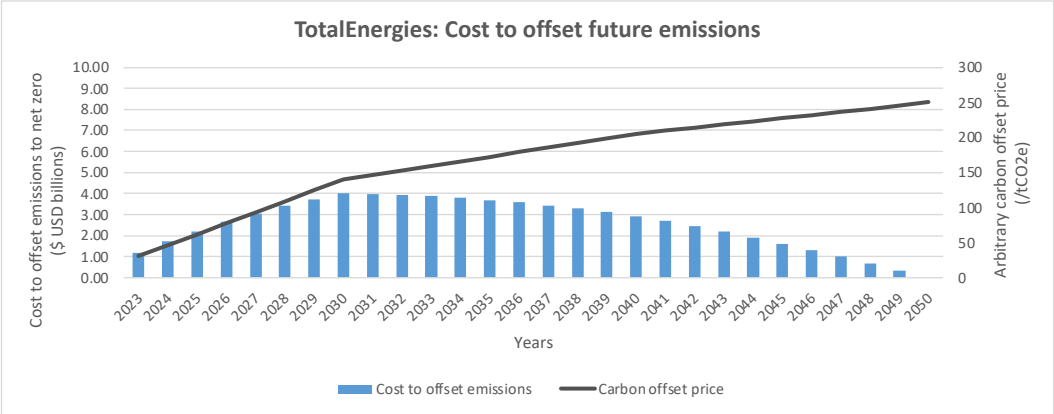

Figure 4.1.10: Chart of costs to offset emissions plotted against forecasted carbon prices for TotalEnergies, 2023 through 2050.

This study is not designed to accurately forecast how much each company will spend on future carbon offsets. Rather, its aim is to project the costs each company could incur in a scenario where global climate policy enforces net zero emissions in a given year. As seen in the figures above, the downside exposure is considerably high, as the majority of annual costs to net out emissions are projected to be above one billion dollars. To an extent, this indicates that the future profitability of oil and gas majors is dependent on global climate policy and enforcement of prices on carbon emissions.

V. LOW CARBON ACTIVITIES ANALYSIS

Preamble on calculations: The purpose of this section is to assess each company's approach to the energy transition by identifying which low carbon technology groups are most likely to be core to future operations. To perform this analysis, the following radar charts are calculated using relative figures to represent different low carbon investments. A weighting of one hundred per cent is assigned to technologies that are prioritized under the company's sustainability report and represented in the respective low carbon investment portfolio. A weighting of fifty per cent is assigned if the company has deployed capital, organically or inorganically, or research and development to the technology, but the technology itself is not prioritized in the company's sustainability report. A weighting of zero per cent is assigned if the technology is not mentioned in the sustainability report and not represented in the company's current investment portfolio.

ExxonMobil: Since establishing its Low Carbon Solutions business in early 2021, ExxonMobil has invested in several emissions-reductions strategies and plans on investing $17 billion in its lower-emission initiatives from 2022 through 2027 (Exxon Mobil Corporation 2023b, 58). The company has focused on carbon capture and storage, hydrogen, and lower-emission fuels, avoiding renewable power and electricity. ExxonMobil has established itself as a global leader in capturing and storing carbon dioxide. With over thirty years of experience, the company has captured more anthropogenic carbon dioxide than any of its counterparts. Its current annual capacity stands at 9 Mta, which represents "an equity share of about one-fifth of the world's carbon capture capacity" (Exxon Mobil Corporation 2023b, 61). Investing across the U.S. and internationally, the company forecasts significant growth in its carbon capture and

storage capacity. Its landmark Baytown blue hydrogen project, coupled with other nearby projects, demonstrates that the company intends to make Houston a carbon capture and storage hub, targeting 100 Mta by 2040. The company has also strategically invested in low-carbon hydrogen, with a current capacity of 1.3 Mta that should drastically increase because of the new Baytown operations. Additionally, the company has invested in lower-emission fuels, such as renewable diesel and sustainable aviation fuel. The company organically targets 200,000 barrels per day of lower-emission fuels by 2030, and its inorganic investments in Imperial Oil (a Canadian affiliate) and a Norwegian joint venture should further increase this figure. The company has also pursued a few alternative emissions-reductions strategies, including nature-based solutions and reduced flaring in the Permian Basin, advanced recycling of plastics in Baytown, and transitioning from unabated coal to liquified natural gas. Evidently, ExxonMobil has gravitated towards mitigative, emissions-reductions strategies rather than investing in renewable energy technologies such as solar and wind (Exxon Mobil Corporation 2023b, 59-68).

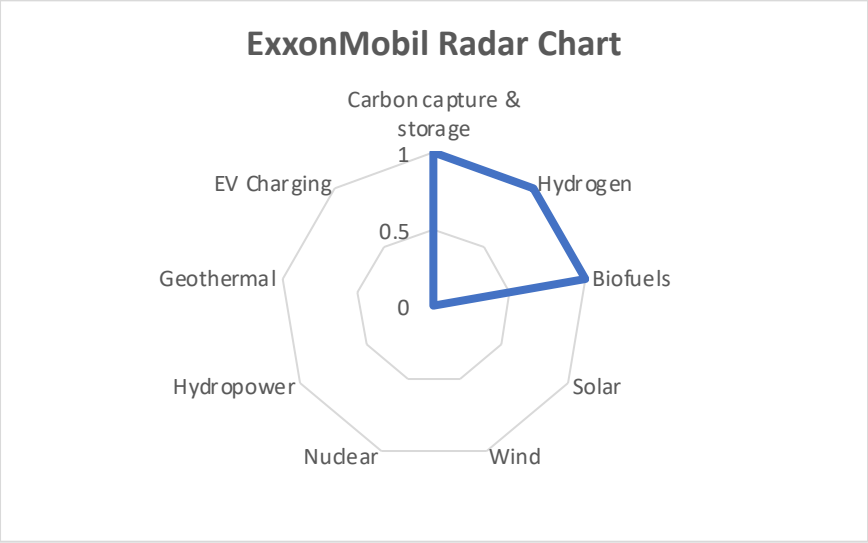

Figure 4.2.1: Radar chart of ExxonMobil's low carbon investment portfolio and research and development contribution.

Chevron: Similar to ExxonMobil, Chevron, operating from its New Energies business, has focused on reducing emissions in its hydrocarbon business while avoiding significant investments in renewable energy technologies. However, in recent years Chevron has made a series of organic and inorganic investments in the renewable space. By 2028, the targeted capital allocation is $8 billion in low carbon investments and $2 billion in carbon reduction projects (Chevron Corporation 2023, 15). Carbon capture, utilization, and storage is a key component of Chevron's net zero ambition. The company operates the Gorgon gas field in Australia, a $3 billion investment and one of the largest carbon capture projects in the world. Despite having the capacity to store 4 Mta, the Gorgon project has consistently fallen short of expectations due to operational issues, forcing Chevron to purchase carbon offsets to align with local policy (Readfearn 2022). Looking forward, Chevron expects to capture 25 Mta by means of CCUS by 2030. The company has also been developing green, blue, and gray hydrogen as a fuel source, holding seventy five patents in hydrogen and signing several contracts with automotive manufacturers. The company has also invested in two hydrogen technology companies, Hydrogenous and Iwatani in the past three years. By 2030, the company targets 150,000 tons of hydrogen per year (Chevron Corporation 2022b, 20-21). Further, the company has several ongoing joint ventures in the renewable fuels space and recently acquired Renewable Energy Group, a renewable diesel company, for $3.15 billion in 2022 (Eller 2022). The company targets 100,000 barrels per day of renewable fuel by 2030. Carbon offsets are another key part of Chevron's sustainability pathway, as the company has invested in soil carbon storage, reforestation, and other nature-based projects to reduce global emissions (Chevron Corporation 2022b, 20-21). In 2021, Chevron entered into a joint venture to invest in Ocergy Inc., an offshore wind turbine technology company in Oakland, notably being the first U.S. oil major to enter the

space (Ghosh 2021). The company is also developing its Hayhurst Solar Power Facility in a joint venture with Algonquin Power & Utilities Corporation, hoping to electrify its operations in the Permian Basin in the future (Chevron Corporation 2022c). Chevron has also committed capital through joint ventures in geothermal development, investing in the Canadian start-up Eavor, and nuclear fusion, funding Zap Energy and TAE Technologies (Chevron Corporation 2022a, 2020; Clifford 2022). Despite having a slightly more diversified portfolio of low carbon investments compared to ExxonMobil, Chevron has been hesitant to integrate renewable energy technologies with its operating assets.

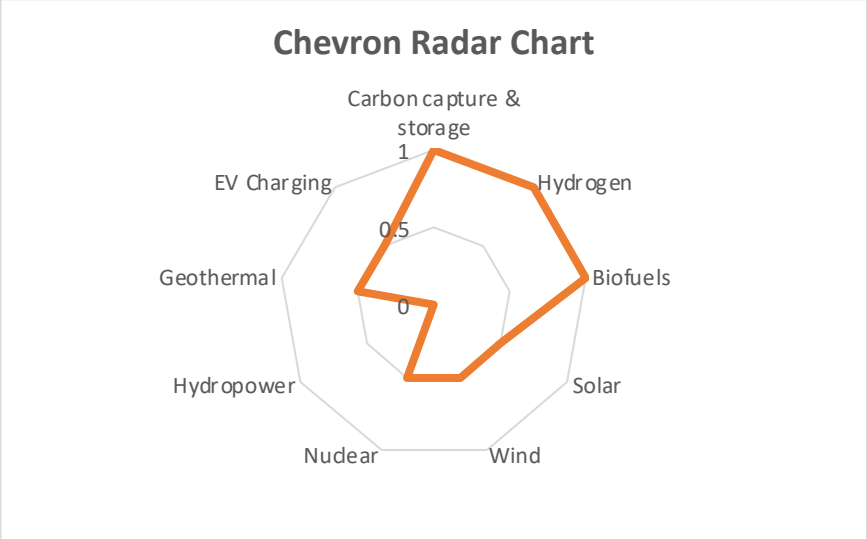

Figure 4.2.2: Radar chart of Chevron's low carbon investment portfolio and research and development contribution.

Shell: Shell's activity in the renewable energy space has been well diversified across the different technology groups. Cash capital expenditure in low carbon solutions was $4.3 billion in 2022, representing around seventeen per cent of total cash capital expenditures, a much higher per cent than its U.S. peers (Shell plc 2023a, 5). A key component of Shell's low carbon business

is electrification. The company currently operates 139,000 electric vehicle charging points and has 6.4 GW in renewable generation capacity. Since 2016, Shell has acquired two leading renewable energy companies, Sprng Energy and Savion, and won multiple global offshore wind bids. The company has also been developing renewable hydrogen and recently added investments in the Netherlands (200 MW capacity) and China (20 MW capacity). In the biofuels space, Shell has 9.5 billion blender liters of capacity, which represents six per cent of global capacity. The company acquired Denmark's Nature Energy, the largest renewable natural gas producer in Europe, and signed a long-term agreement to buy ethanol from sugar-cane waste from Brazil's Raízen. Further, the company is one of the world's leading distributors of liquified natural gas and has helped countries replace coal while further reducing emissions by using carbon capture and storage technologies. Shell spent $220 million on carbon capture and storage technologies in 2022 and currently has a capacity of 0.4 Mta. The company looks to expand this capacity with its Northern Lights CCS joint venture and its equity stake in Canada's Atlas Sequestration Hub. The company also reduces emissions with nature-based and technology-based projects that create carbon offsets, similar to ExxonMobil and Chevron (Shell plc 2023a, 17-21). Additionally, Shell and D4 were granted a license in 2021 to develop at least 200 MW of geothermal energy in Holland, further expanding the company's low carbon portfolio (Cariaga 2021). Evidently, Shell has transitioned from a hydrocarbon company to an energy company, investing in diversified technologies across the value chain of its products.

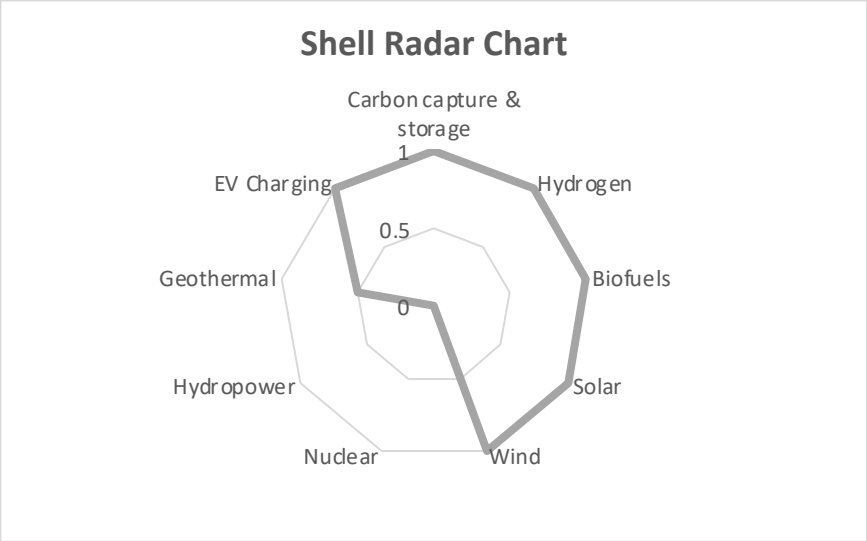

Figure 4.2.3: Radar chart of Shell's low carbon investment portfolio and research and development contribution.

BP: Like Shell, BP has rebranded as an energy company rather than focusing solely on hydrocarbons. BP was the first of the majors to start investing in renewable energies in the 1980s. After the infamous 2010 Deep Water Horizon oil spill, BP closed down a majority of its green energy investments, but since then the company has re-established its presence in the renewable energy industry (Murray 2020). BP's current transition strategy revolves around five growth engines: bioenergy, convenience, electric vehicle charging, renewables and hydrogen. Capital expenditures in these engines are targeted to be $6-8 billion in 2025 and $7-9 billion in 2030 (BP plc 2023b, 18). By 2030, the company targets 50 GW of renewable energy generating capacity (BP plc 2022). Its portfolio of solar and wind energy projects is highlighted by Lightsource BP (Europe's largest solar developer), the Morgan and Monda offshore wind projects in Ireland, and the Morven offshore wind project in Scotland. BP has also established a strong bioenergy business, marked by its recent acquisition of Archaea Energy, the leading renewable natural gas producer in the U.S. (BP plc 2023b, 28-38). The company also seeks to expand its electric vehicle charging network, with 22,000 charge points currently and a target of

over 100,000 by 2030 (BP plc 2023a). Its electric vehicle charging business has expanded rapidly since its acquisition of Chargemaster, the UK's largest electric vehicle charging network (BP plc 2018a). BP has been developing its global position in hydrogen technologies as well, with projects in the East Coast Cluster and its operational interest in the Australian Renewables Energy Hub (which has a capacity of 1.6 Mta). Recently, BP has integrated carbon capture and storage with some of its operations, notably the NZTP joint venture. The company looks to use carbon capture and storage technologies in its production of blue hydrogen and electricity in the future (BP plc 2023b, 28-34). BP is also a part-owner of Eavor alongside Chevron, working to produce deep-geothermal renewable energy solutions (Collins 2021). All in all, BP has established a strong portfolio of renewable energy projects while employing mitigative strategies to reduce emissions from hydrocarbon projects.

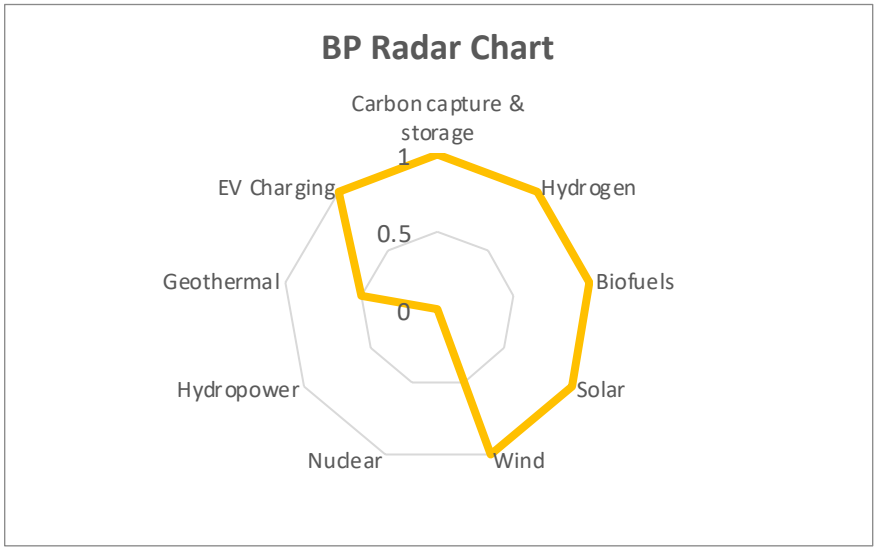

Figure 4.2.4: Radar chart of BP's low carbon investment portfolio and research and development contribution.

TotalEnergies: To achieve net zero emissions, TotalEnergies is focused on improving energy efficiency, reducing flaring and methane emissions, supplying renewable electricity, and

using carbon capture and storage technologies. The company wants to become one of the top five producers of renewable electricity, declaring that it intends to finance over $60 billion in investments in renewable power generation capacity by 2030. In 2021, TotalEnergies' gross installed capacity for renewable power, comprised of photovoltaic solar energy and offshore wind energy, stood at 10 GW, and by 2030 the company targets an increase to 100 GW. The company's solar and wind (offshore and onshore) projects are integrated across every continent, with the largest projects being New York Bight (3 GW), West of Orkney (2 GW), and Bada (2 GW). In 2021, the company expanded its renewable energy portfolio by acquiring minority interest in Adani Green Energy Limited, the world's largest solar developer, purchasing four solar projects in the U.S. from SunChase and another twelve in a joint venture with 174 Power Global, and operating France's most extensive battery storage site. Within the road transportation sector, the company has deployed electric vehicle charge points in Europe and Asia and aims to have 150,000 charge points by 2025. The company has supplemented its charging infrastructure with the development high-performance automotive batteries as part of its joint venture, Automotive Cells Company. TotalEnergies has also been developing carbon capture and storage solutions since 1996, and in 2021 it allocated $100 million to carbon capture and storage solutions. The company targets 10 Mta in carbon capture capacity by 2030. The company has invested in a series of transport and storage projects, including the Northern Lights project in Norway (partnering with Equinor and Shell), the Aramis project in the Netherlands, and the Northern Endurance Partnership in the United Kingdom. The company has also explored the implementation of carbon capture projects in its hydrogen refineries. The company has been rapidly expanding its bioenergy business as well, developing two biorefineries in France and investing in new generation biofuels. It looks to expand its production capacity from 500 kt

(kilotons) in 2022 to 5 Mt in 2030 (TotalEnergies SE 2022, 14-21). Additionally, TotalEnergies has a small presence in the hydropower industry, supplying lubricants for hydro generation applications (TotalEnergies SE 2023a). Further, the company, employing ZeGen Energy, recently completed a geothermal assessment project, analyzing the possible inclusion of geothermal energy in offshore renewable energy production (ZeGen 2023). All told, TotalEnergies has expanded its renewable energy portfolio and committed research and development expenditures to explore new energies and technologies, positioning itself ahead of its peers from a low carbon perspective.

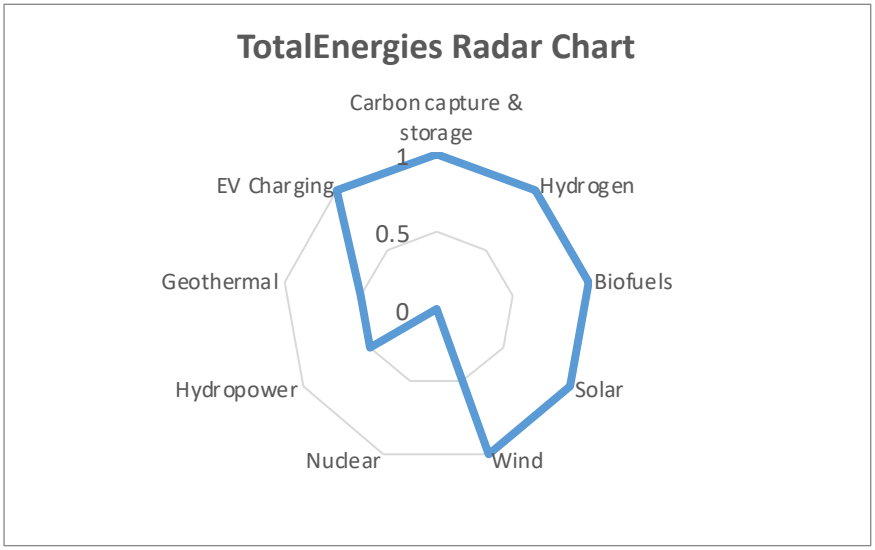

Figure 4.2.5: Radar chart of TotalEnergies' low carbon investment portfolio and research and development contribution.

Analysis of U.S. vs. European majors: As seen in the chart below, the European majors have entered the solar and wind energy space while also deploying electric vehicle charge points and researching integration with geothermal energy. On the other hand, the U.S. majors have generally tended away from renewable power generation and focused on strategies to reduce

emissions and capture residual emissions. The U.S. majors lag the European majors, likely due to climate policy. Since 2016, the European majors have had a relatively proactive response, diversifying their low carbon portfolios to match the future trends in hydrocarbon and renewable energy usage. The U.S. majors have been relatively reactive, investing in mitigative technologies and largely ignoring the onset of renewables.

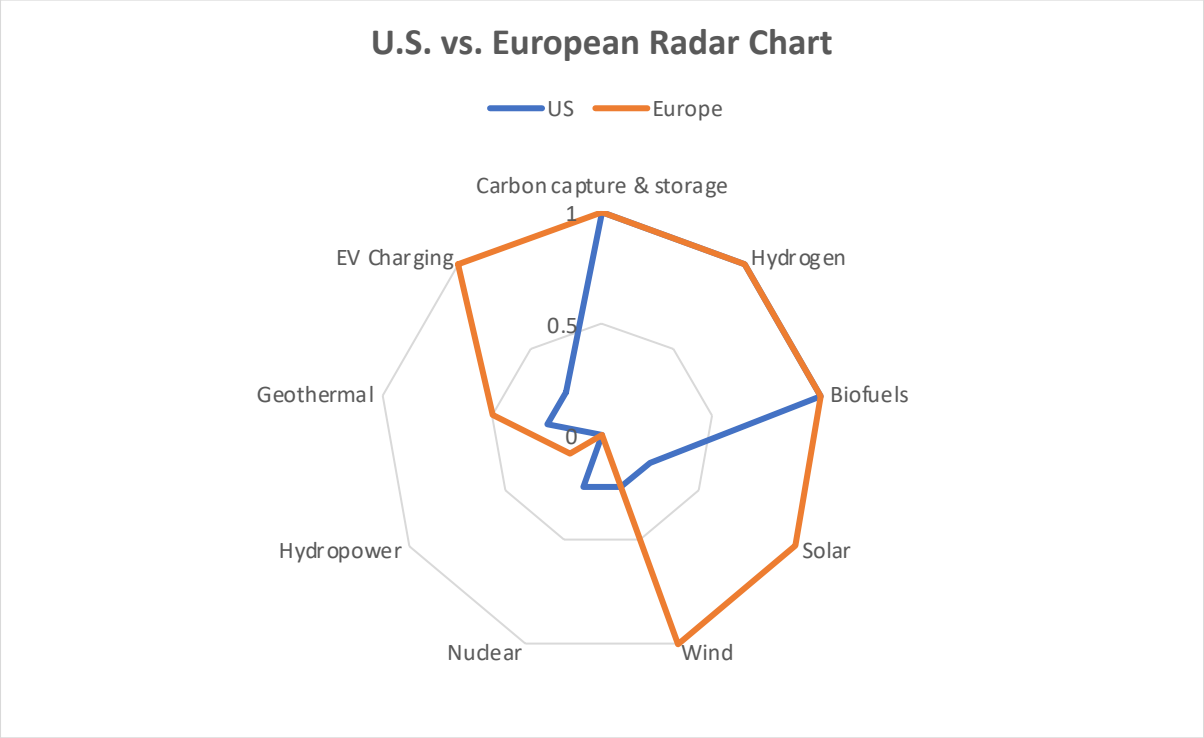

Figure 4.2.6: Radar chart plotting the U.S. majors' low carbon investments and research and development contributions against those of the European majors. The data was compiled by averaging the scores of U.S. majors (ExxonMobil, Chevron) and European majors (Shell, BP, TotalEnergies).

VI. MARKET PERCEPTION OF THE ENERGY TRANSITION

Event Studies: Methods

Importance: Understanding how public markets react to oil majors announcing targets and investments in the low carbon space will show whether investors believe these actions create or destroy value for the individual firm. The analysis aims to be idiosyncratic, as it only shows the impact to the individual firm and does not capture any systematic or market-wide risks.

Methodology: In order to conduct these event studies, the 'normal' or 'predicted' returns for each company must be known. The formula shown below is used to calculate the predicted returns prior to the event study for firm *i*:

$$(Normal\ Return)_{i,t} = a + b_i * (Market\ Returns)_t$$

The S&P 500 is used as the independent variable, indexing the ordinary market returns. While the S&P 500 represents large, publicly-traded U.S. firms, it is still indicative of general market trends and falls in line with CapIQ's independent variable system. Beta represents firm *i's* covariance with the general market, and alpha represents the excess returns of firm *i* with respect to the benchmark index. Finally, the timeframe 't' represents the timeline of the event study, and beta and alpha are estimated values using a prior timeline. Then, in order to calculate the cumulative abnormal returns (CAR), the following formulas are used:

$$(Abnormal\ Returns)_{i,t} = (Returns)_{i,t} - (Normal\ Returns)_{i,t}$$

$$CAR_{i,t} = \sum_{t=0}^{t} (Abnormal\ Returns)_i$$

In this study, CAR is set to a timeframe of (-2,2). In other words, the stock price is assessed on the day of the announcement, as well as the prior two days and the following two days.

According to relevant literature, events can have an impact on the share price in the days prior to the announcement due to leakage and insider information, and the market may also have a delayed reaction to pricing in the news, hence the inclusion of t = (-2,-1,0,1,2). Because of the multitude of events being studied, this process was simplified by using CapIQ's event study model. Under the estimation parameters, this study uses the CAPM risk model to find alpha and beta, one hundred prior trading days to calculate normal returns, and a five day gap between the estimation window and the event window. Finally, after calculating CAR, this study uses cumulative average abnormal returns (CAAR), by averaging the CARs of different event studies, to assess possible theories and scenarios.

Selection of events: The following events are chosen based on a combination of factors. Each event is isolated from other simultaneous and relevant firm press releases or systematic market news and must involve an investment, research and development expenditure, or change in governance (for example: new ESG directors, new climate reports, new emissions or spending targets) in the low carbon space. Note that carbon offset projects that are not related to firm operations but are solely run to reduce net emissions are grouped into sustainability governance. Additionally, oil and gas investments and divestitures are not included for the purpose of this study. In the past three years, macroeconomic events could skew the abnormal return figures. Due to the effects of the global Covid-19 pandemic on global supply and demand of oil, natural gas, and alternatives, oil majors realized a sizable loss in early 2020. Further, in 2021 and 2022, many oil majors recorded record profits due to the Russia-Ukraine conflict and the steep increase in commodity prices, specifically crude oil and natural gas. These effects are shown in the following visual.

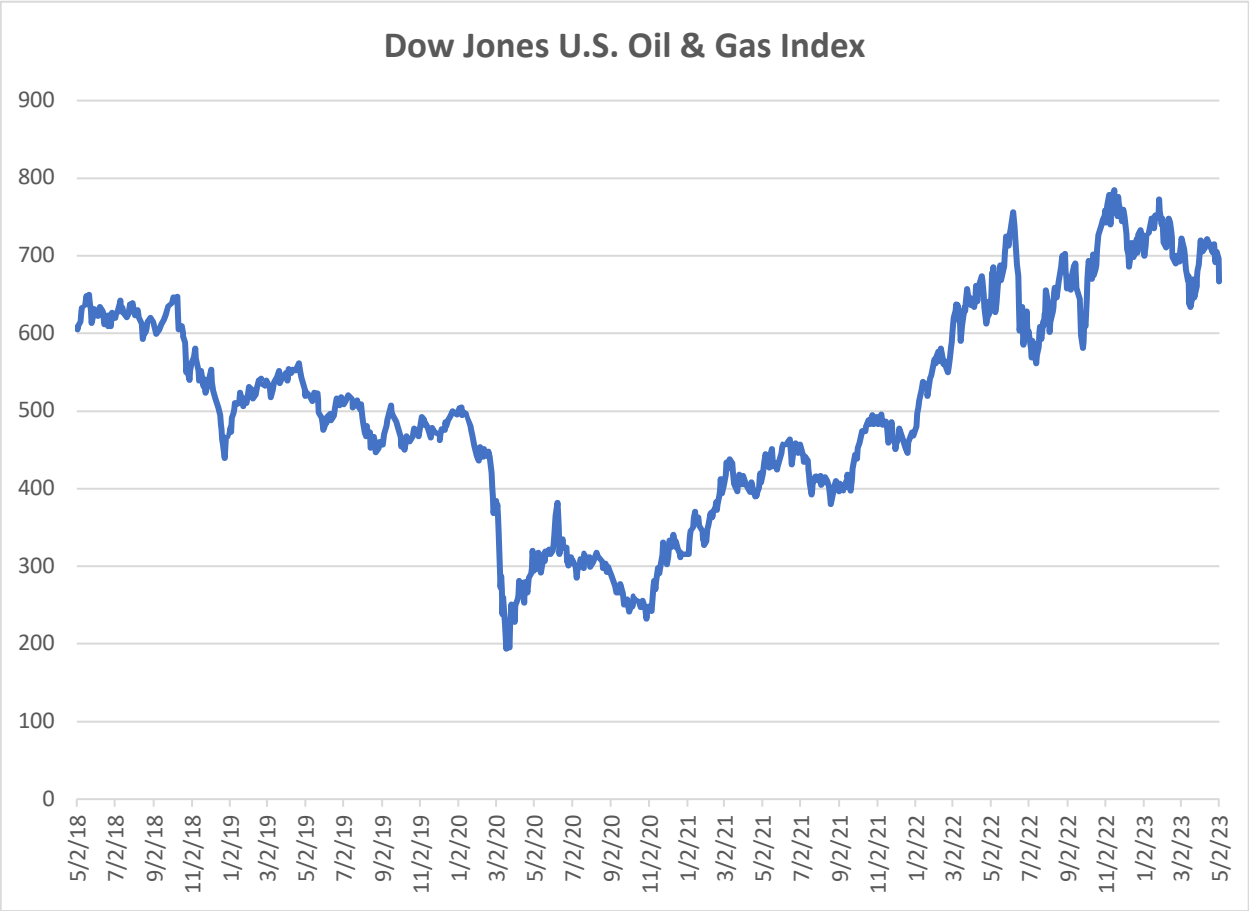

Figure 5.1.1: Graphical representation of the Dow Jones U.S. Oil & Gas Index, dating from May of 2018 to May of 2023 (S&P Dow Jones Indices 2023)

The study incorporates firm-specific press releases dating from the beginning of 2018 to the beginning of 2023. While crude oil and natural gas prices were more stable between 2016 and 2018, there was significantly less environmental capital and research and development expenditures by oil majors; therefore, the study elects to analyze a five year window that captures the majority of events related to this paper. Additionally, the betas of each firm should capture some of the volatility of the oil majors' share prices due to fluctuations in commodity prices.

Event Studies: Firm-specific

ExxonMobil:

The chart shown below depicts the relevant announcements being analyzed for ExxonMobil, as well as the CARs for each event.

Date of Event	Event	Classification	CAR(-2,2)
1/26/23	ExxonMobil moves forward with largest renewable diesel facility in Canada	Biofuels	-0.28%
12/14/22	ExxonMobil starts operations at large-scale advanced recycling facility	Plastics Recycling	1.31%
11/29/22	ExxonMobil, Mitsubishi Heavy Industries form carbon capture technology alliance	Carbon Capture	-4.64%
11/12/22	ExxonMobil and Pertamina advance regional carbon capture and storage project in Indonesia	Carbon Capture	-0.44%
10/12/22	Landmark emissions-reduction project in Louisiana announced; CF Industries, ExxonMobil, EnLink Midstream to collaborate	Carbon Capture	-1.23%
6/27/22	ExxonMobil, CNOOC and Shell to pursue carbon capture and storage hub in China	Carbon Capture	-1.89%
5/13/22	ExxonMobil and Indonesia's Pertamina to advance cooperation in carbon capture and storage	Carbon Capture	7.08%
4/14/22	ExxonMobil begins design studies for South East Australia carbon capture hub in Gippsland	Carbon Capture	3.19%
3/1/22	ExxonMobil planning hydrogen production, carbon capture and storage at Baytown complex	Hydrogen; Carbon Capture	4.30%
1/18/22	ExxonMobil announces ambition for net zero greenhouse gas emissions by 2050	Sustainability Governance	7.24%
1/11/22	ExxonMobil expands interest in biofuels, acquires stake in Biojet AS	Biofuels	4.15%
12/6/21	ExxonMobil plans for net zero emissions in Permian Basin operations by 2030	Sustainability Governance	-0.62%
11/9/21	Why we're investing $15 billion in a lower-carbon future	Sustainability Governance	2.25%
11/2/21	ExxonMobil and Pertamina to evaluate carbon capture and storage in Indonesia	Carbon Capture	-2.39%
10/21/21	ExxonMobil plans to increase carbon capture at LaBarge, Wyoming facility	Carbon Capture	0.65%
10/11/21	ExxonMobil to build its first large-scale plastic waste advanced recycling facility	Plastics Recycling	0.72%
9/29/21	ExxonMobil and Rosneft to cooperate in carbon management	Hydrogen; Carbon Capture	8.81%

8/25/21	ExxonMobil affiliate to produce renewable diesel to help reduce transportation emissions in Canada	Biofuels	3.90%
7/16/21	ExxonMobil to participate in carbon capture and storage project in Scotland	Carbon Capture	-8.46%
4/22/21	ExxonMobil expands renewable fuels agreement with Global Clean Energy Holdings	Biofuels	-4.03%
3/30/21	ExxonMobil and Porsche test lower-carbon fuel in race conditions	Biofuels	-2.94%
2/25/21	ExxonMobil tests advanced recycling of plastic waste at Baytown facilities	Plastics Recycling	2.65%
2/1/21	ExxonMobil Low Carbon Solutions to commercialize emissions-reduction technology	Carbon Capture	1.61%
12/14/20	ExxonMobil announces emission reduction plans; expects to meet 2020 goals	Sustainability Governance	1.92%
9/21/20	Thermostat, sees promise in direct air capture technology	Carbon Capture	-1.87%
8/11/20	ExxonMobil and Global Clean Energy Holdings sign agreement for renewable diesel	Biofuels	0.45%
7/24/20	ExxonMobil collaborates on discovery of new material to enhance carbon capture technology	Carbon Capture	0.14%
11/6/19	ExxonMobil, FuelCell Energy expand agreement for carbon capture technology	Carbon Capture	2.48%
8/26/19	ExxonMobil and Mosaic Materials to explore new carbon capture technology	Carbon Capture	-0.91%
6/27/19	ExxonMobil and Global Thermostat to advance breakthrough atmospheric carbon capture technology	Carbon Capture	-1.32%
5/8/19	ExxonMobil to invest up to $100 million on lower-emissions R&D with U.S. National Labs	Sustainability Governance	2.00%
1/23/19	ExxonMobil and Renewable Energy Group partner with Clariant to advance cellulosic biofuel research	Biofuels	-1.45%
9/20/18	ExxonMobil to join Oil and Gas Climate Initiative	Sustainability Governance	2.84%
5/23/18	ExxonMobil announces greenhouse gas reduction measures	Sustainability Governance	-3.27%
3/6/18	ExxonMobil and Synthetic Genomics algae biofuels program targets 10,000 barrels per day by 2025	Biofuels	-2.93%
2/2/18	ExxonMobil releases Energy & Carbon Summary and Outlook for Energy	Sustainability Governance	-7.44%

Figure 5.2.1: ExxonMobil's relevant press releases and CARs for the event studies, organized by descending dates.

The events and respective CARs can be used to provide an aggregate analysis of ExxonMobil's climate-related announcements. The following chart analyzes the cumulative abnormal returns

for all thirty-six events based on the summation of the daily abnormal returns for the days relative to each event.

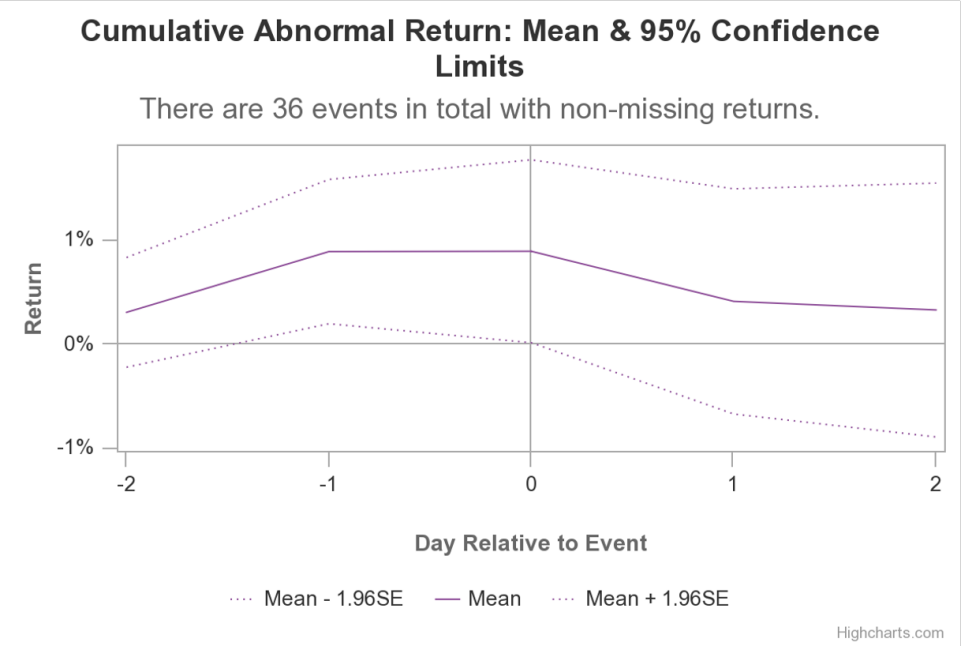

Figure 5.2.2: ExxonMobil's cumulative abnormal returns summed on days relative to event.

At first glance, this figure appears to indicate that, on average, environmental announcements lead to an increase in share price; in other words, environmental announcements create value for shareholders. However, further analysis is required to determine what leads to these results.

The following analysis is split into two parts: annual changes in CAAR and variances based on classification. The purpose of looking at annual changes is to see if the market has changed its views on the value of low carbon projects and targets over this timeframe. Further, looking at CAARs based on classification shows whether the market tends to value different types of low carbon projects and targets in different ways.

$CAAR_{2018}$	**-2.70%**
Count	*4*
StDev	*4.22%*
$CAAR_{2019}$	**0.16%**
Count	*5*
StDev	*1.91%*
$CAAR_{2020}$	**0.16%**
Count	*4*
StDev	*1.56%*
$CAAR_{2021}$	**0.18%**
Count	*12*
StDev	*4.38%*
$CAAR_{2022/2023}$	**1.71%**
Count	*11*
StDev	*3.81%*

Figure 5.2.3: ExxonMobil CAARs for each year, based on the average of each event's CAR in a given year. The number of observations and standard deviation of each year's CAAR are shown also.

$CAAR_{Hydrogen,\ Carbon\ Capture}$	**0.30%**
Count	*17*
StDev	*4.14%*
$CAAR_{Biofuels}$	**-0.39%**
Count	*8*
StDev	*3.10%*
$CAAR_{Recycling}$	**1.56%**
Count	*3*
StDev	*0.99%*
$CAAR_{Sustainability\ Governance}$	**0.62%**
Count	*8*
StDev	*4.42%*

Figure 5.2.4: ExxonMobil CAARs, number of observations, and standard deviations for each classification.

As shown in the tables above, the CAARs tend to increase each year, potentially indicating that the market has increased its valuation of low carbon projects and targets. They also indicate that, on average, investments in advanced recycling projects yield the highest abnormal returns, while investments in biofuels projects yield the lowest abnormal returns. These results are not entirely conclusive, given that the abnormal returns of each event could be correlated to price volatility in

crude oil and natural gas or risks that solely effect the oil and gas industry. In order to determine if the market has increased its valuation of low carbon events or if the market tends to value ExxonMobil's different types of low carbon announcements in this order, another study would need to isolate all other idiosyncratic risks and risks that temporarily impact certain industries but not all.

Chevron:

The chart below outlines Chevron's relevant press releases and their respective CARs. Chevron's low carbon portfolio is more diversified than ExxonMobil's, hence the additional classifications for solar, wind and nuclear.

Date of Event	Event	Classification	CAR(-2,2)
3/17/23	Chevron and JERA sign MOU to explore carbon capture and storage project in United States and Australia	Carbon Capture	-2.15%
2/26/23	Chevron announces lower carbon LNG fleet modification project with Sembcorp Marine	Biofuels	1.50%
9/28/22	Chevron New Energies backs hydrogen-powered maritime tech	Hydrogen	0.50%
8/11/22	New solar energy field will help lower carbon intensity	Solar	0.21%
5/23/22	Carbon capture and storage project in California takes root	Carbon Capture	1.97%
5/6/22	Chevron embarks on carbon offsets restoration project	Sustainability Governance	-2.35%
4/19/22	Chevron joins coalition to help reduce aviation carbon intensity	Sustainability Governance	-6.11%
4/6/22	Chevron joins Global Centre for Maritime Decarbonisation	Sustainability Governance	1.32%
2/28/22	Chevron announces agreement to acquire Renewable Energy Group	Biofuels	10.18%
12/1/21	Chevron announces $15 billion capital and exploratory budget for 2022	Sustainability Governance	2.17%
11/1/21	Brightmark, Chevron announce first renewable natural gas at lawnhurst farms	Biofuels	-2.80%
10/11/21	Chevron sets net zero aspiration and new GHG intensity target	Sustainability Governance	2.61%

9/14/21	Chevron accelerates lower carbon ambitions	Sustainability Governance	2.51%
9/2/21	Chevron, Bunge announce proposed joint venture to create renewable fuel feedstocks	Biofuels	-0.53%
7/15/21	Chevron and Cummins announce strategic collaboration on hydrogen	Hydrogen	-6.93%
5/11/21	Chevron, Clean Energy Fuels extend a-port initiative to reduce emissions	Sustainability Governance	-0.93%
4/21/21	Chevron, Toyota pursue strategic alliance on hydrogen	Hydrogen	-1.87%
3/4/21	Chevron, Microsoft, Schlumberger collaborate on carbon negative bioenergy	Biofuels	10.37%
2/17/21	Chevron, Brightmark expand partnership on dairy biomethane fuel projects	Biofuels	6.15%
1/14/21	Chevron invests in carbon capture and utilization startup	Carbon Capture	3.62%
12/3/20	Chevron announces $14 billion capital and exploratory budget for 2021	Sustainability Governance	2.60%
10/7/20	Chevron, Brightmark partner on dairy biomethane fuel projects	Biofuels	0.75%
9/24/20	CalBio, dairy farmers and Chevron announce first RNG	Biofuels	-4.18%
8/12/20	Chevron invests in nuclear fusion start-up	Nuclear	3.70%
8/5/20	Chevron announces first 100% renewable base oil production	Biofuels	-0.07%
7/30/20	Chevron and Algonquin announce agreement to co-develop renewable power projects	Solar; Wind	-8.83%
12/10/19	Chevron announces $20 billion capital and exploratory budget for 2020	Sustainability Governance	1.05%
10/3/19	Chevron sets new GHG reduction goals	Sustainability Governance	-3.99%
2/7/19	Chevron issues update to climate report for investors	Sustainability Governance	-2.18%
12/6/18	Chevron announces $20 billion capital and exploratory budget for 2019	Sustainability Governance	0.37%
6/20/18	Chevron Technology Ventures launches Future Energy Fund	Sustainability Governance	1.92%
3/1/18	Chevron issues second climate report for investors	Sustainability Governance	1.22%

Figure 5.2.5: Chevron's relevant press releases and CARs for the event studies, organized by descending dates.

The aggregate analysis of abnormal returns for all thirty-two events is shown below, as well as the CAARs organized by year and by classification.

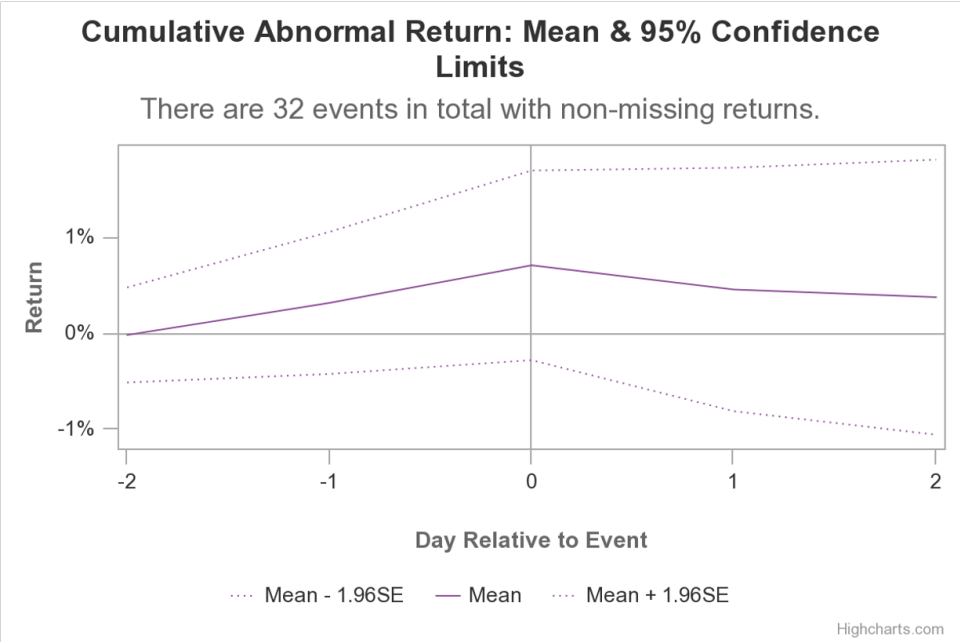

Figure 5.2.6: Chevron's cumulative abnormal returns summed on days relative to event.

$CAAR_{2018}$	**1.17%**
Count	*3*
StDev	*0.78%*
$CAAR_{2019}$	**-1.71%**
Count	*3*
StDev	*2.55%*
$CAAR_{2020}$	**-1.00%**
Count	*6*
StDev	*4.70%*
$CAAR_{2021}$	**1.31%**
Count	*11*
StDev	*4.67%*
$CAAR_{2022/2023}$	**0.56%**
Count	*9*
StDev	*4.42%*

Figure 5.2.7: Chevron CAARs, number of observations, and standard deviations for each year.

$CAAR_{Hydrogen}$	**-2.77%**
Count	*3*
StDev	*3.79%*
$CAAR_{Carbon\ Capture}$	**1.15%**
Count	*3*
StDev	*2.97%*
$CAAR_{Biofuels}$	**2.38%**
Count	*9*
StDev	*5.32%*
$CAAR_{Solar,\ Wind}$	**-4.31%**
Count	*2*
StDev	*6.39%*
$CAAR_{Nuclear}$	**3.70%**
Count	*1*
StDev	*n/a*
$CAAR_{Sustainability\ Governance}$	**0.01%**
Count	*14*
StDev	*2.73%*

Figure 5.2.8: Chevron CAARs, number of observations, and standard deviations for each classification.

Similar to ExxonMobil, Chevron's abnormal returns aggregate to a slightly positive figure over time. Breaking down the aggregate results, Chevron's CAARs based on each year and each classification are relatively inconclusive, with high standard deviations around the mean. However, it is particularly noteworthy that Chevron announced a major project in the biofuels space, its acquisition of Renewable Energy Group, which yielded a CAR above ten per cent. On the other hand, Chevron's first major solar and wind project since 2017, its partnership with Algonquin, yielded a CAR below negative eight per cent. Interpreting this, the market appears to value major biofuels projects as positive net present value projects and major solar and wind projects as negative net present value projects. This would intuitively make sense, as biofuels are largely integrated into Chevron's long-term operational plans, while the company's activity in the solar and wind space has been historically unsuccessful and primarily inorganic.

Shell:

The chart below shows Shell's relevant announcement and the CARs associated with each one. Shell has acquired equity in a wide range of renewable power, renewable fuel, and hydrogen companies, and the event study will capture the impact of the initial announcements, not the closing sales. On January 29, 2022, Shell changed its share structure, collapsing its two lines of ordinary shares into one and simplifying its dividend and taxation structure (Shell plc 2022b). Due to this, CapIQ does not register U.S.-based trading data prior to this date for event studies; thus, all events being analyzed occurred after the share simplification.

Date of Event	Event	Classification	CAR(-2,2)
3/28/23	Shell publishes reports on Sustainability, Climate & Energy Transition Lobbying and Payments to Governments	Sustainability Governance	8.85%
3/16/23	Shell reports good progress on journey to net-zero emissions	Sustainability Governance	-8.89%
12/15/22	Shell and Eneco win bid to develop 760 MW offshore wind power in the Netherlands at Hollandse Kust (west) VI	Wind	0.46%
11/28/22	Shell to acquire renewable natural gas producer Nature Energy	Biofuels	1.70%
7/6/22	Shell to start building Europe's largest renewable hydrogen plant	Hydrogen	-1.10%
4/29/22	Shell to acquire Sprng Energy group, one of India's leading renewable power platforms	Solar; Wind	1.64%
4/20/22	Strong progress towards net zero for Shell	Sustainability Governance	-3.82%
4/5/22	Shell publishes reports on Sustainability, Industry Associations and Payments to Governments	Sustainability Governance	-2.52%
2/25/22	Shell joint venture Atlantic Shores wins acreage in New York Bight, expanding offshore wind market share	Wind	-4.35%
2/14/22	Ed Daniels appointed Strategy, Sustainability and Corporate Relations Director	Sustainability Governance	-3.35%

Figure 5.2.9: Shell's relevant announcements and CARs for event study, organized by descending dates.

Shown below are Shell's cumulative results for all ten events. Additionally, the CAARs are broken down into 2022 and 2023 event studies.

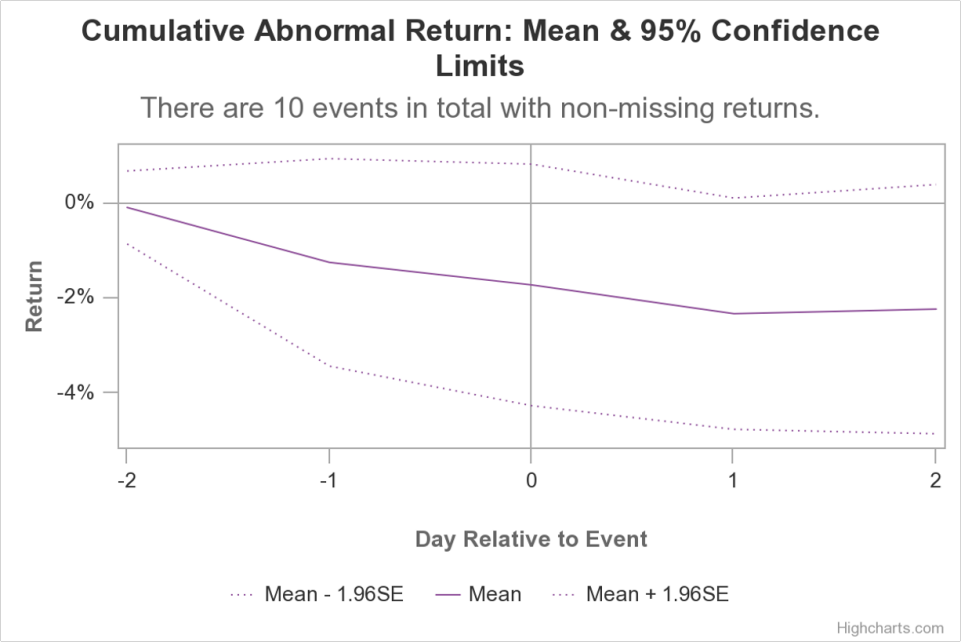

Figure 5.2.10: Shell's cumulative abnormal returns summed on days relative to event.

$CAAR_{2022}$	**-1.42%**
Count	8
StDev	2.45%
$CAAR_{2023}$	**-0.02%**
Count	2
StDev	12.54%

Figure 5.2.11: Shell CAARs, number of observations, and standard deviations for each year.

Due to the limited data sample, this case study elects to only look at year-over-year CAARs from 2022 to 2023. While these limitations make it difficult to look at changes in the market valuation of Shell's low carbon investments, there is one unusual result. In 2022, a very profitable year for oil and gas companies, Shell's CAAR was -1.42%. This implies that, on average, the market

believed the company's low carbon activity destroyed value rather than creating it. As stated earlier, these results would require further analysis, but in aggregate it appears that Shell's recent low carbon actively has been slightly dilutive.

BP:

The chart below displays the relevant low carbon press releases for BP between 2018 and 2023. The company has notably taken an early stance on the energy transition, hence the extensive data set being evaluated.

Date of Event	Event	Classification	CAR(-2,2)
3/1/23	BP Pulse and APCOA to build EV hubs across Europe	EV / EV Charging	-1.62%
1/30/23	BP Energy Outlook 2023 explores key trends and uncertainties surrounding the energy transition	Sustainability Governance	0.59%
1/18/23	BP reveals plans to evaluate expansion of Germany's green energy port with a new hydrogen hub	Hydrogen	-0.25%
1/10/23	BP brings green energy and jobs to Ohio with construction of new utility-scale solar project	Solar	-0.52%
12/15/22	BP invests $20m AUD in low-cost, rapid development solar provider 5B	Solar	1.07%
12/8/22	BP to explore potential for green hydrogen production in Egypt	Hydrogen	-3.58%
11/22/22	25% less CO2 compared to pure fossil fuels: Aral pilots two new lower carbon fuels in Germany	Biofuels	1.03%
11/8/22	BP and Mauritania to explore green hydrogen at scale	Hydrogen	-4.12%
10/17/22	BP accelerates and expands in bioenergy, agreeing to buy leading US biogas company Archaea Energy	Biofuels	0.54%
9/27/22	Hertz, BP collaborate to accelerate EV charging in North America	EV / EV Charging	-5.14%
7/27/22	BP opens its first electric truck charging facilities to support the decarbonization of transport	EV / EV Charging	4.28%
6/15/22	BP to lead and operate one of the world's largest renewables and green hydrogen energy hubs based in western Australia	Hydrogen	-14.01%

5/23/22	Rio Tinto and BP sign one-year trial of marine biofuels	Biofuels	2.24%
5/12/22	BP bids for offshore wind in the Netherlands	Wind	4.79%
4/28/22	Volkswagen Group and BP launch strategic partnership to rapidly roll-out EV fast charging in Europe	EV / EV Charging	0.56%
3/30/22	BP's response to the Climate Action 100+ Net Zero Company Benchmark	Sustainability Governance	-4.09%
3/23/22	BP and Marubeni form strategic partnership to pursue offshore wind in Japan	Wind	7.09%
3/11/22	Aberdeen City Council and BP sign joint venture agreement to develop city hydrogen hub	Hydrogen	-6.95%
2/3/22	BP acquires 30% stake in the UK's largest provider of low emission hydrogenated vegetable oil fuels	Biofuels	6.66%
1/17/22	BP and EnBW successful in ScotWind offshore wind bid	Wind	5.15%
12/15/21	BP and partners award first engineering contracts advancing major UK power and carbon capture projects	Carbon Capture	-2.20%
12/2/21	BP acquires c. 29% stake in major UK provider of biomethane for heavy goods vehicles, Gasrec	Biofuels	6.83%
10/27/21	BP and Daimler Truck AG to accelerate the deployment of hydrogen infrastructure, supporting the decarbonization of UK freight transport	Hydrogen	-4.26%
10/13/21	Lightsource BP launches Bighorn Solar project in Colorado – powering world's first steel mill to run almost entirely on solar	Solar	1.20%
9/30/21	BP leads $25m Series A round in EV ride-hailing and charging start-up BluSmart	EV / EV Charging	8.18%
9/20/21	Lightsource BP further accelerating growth, now targeting 25GW solar developments by 2025	Solar	2.02%
8/11/21	BP study confirms feasibility of large-scale production of green hydrogen and green ammonia using renewable energy in Australia	Hydrogen	0.27%
8/5/21	BP bolsters UK blue hydrogen plans by reaching agreements with more potential customers	Hydrogen	4.82%
7/22/21	BP teams up with Quaybridge to accelerate offshore wind growth	Wind	3.19%
7/14/21	BP and EnBW announce Morgan and Mona offshore wind projects in the Irish Sea, launch supplier registration portal	Wind	-8.93%
6/24/21	Lightsource first Spanish project powers up in Zaragoza	Solar	-2.94%
6/14/21	BP, Aker and Statkraft join forces for offshore wind in the Norwegian North Sea	Wind	0.38%

6/1/21	BP boosts its renewables business in the US with 9GW solar acquisition from 7X Energy	Solar	4.30%
5/13/21	BP and CEMEX team up on net zero emissions	Sustainability Governance	1.18%
3/18/21	BP plans UK's largest hydrogen project	Hydrogen	-5.29%
3/9/21	Lightsource BP solar farm powers bp service stations with 100% renewable energy in Australia	Solar	-4.32%
2/15/21	Lightsource BP secures a new 845MW pipeline in Spain	Solar	6.38%
2/4/21	Rosneft and BP agree to cooperate on carbon management and sustainability	Sustainability Governance	-4.84%
1/29/21	BP completes entry into offshore wind, with strategic partner Equinor	Wind	-10.12%
12/16/20	BP acquires majority stake in largest US forest carbon offset developer Finite Carbon	Sustainability Governance	-2.13%
11/10/20	BP and Ørsted to create renewable hydrogen partnership in Germany	Hydrogen	18.14%
10/8/20	UK's largest ever EV infrastructure contract awarded to BP Chargemaster	EV / EV Charging	-2.31%
9/14/20	BP Energy Outlook 2020	Sustainability Governance	0.90%
8/19/20	Air BP and Neste to offer increased volume of sustainable aviation fuel in Europe	Biofuels	-7.25%
8/4/20	From International Oil Company to Integrated Energy Company: BP sets out strategy for decade of delivery towards net zero ambition	Sustainability Governance	1.32%
7/24/20	Aral to build more than 100 ultra-fast charging points at retail sites in Germany	EV / EV Charging	-2.19%
5/12/20	BP response to the Transition Pathway Initiative's briefing paper on 'Carbon Performance of European Integrated Oil and Gas Companies'	Sustainability Governance	-3.25%
3/19/20	Lightsource BP completes financing on 260 MW solar project in Texas	Solar	6.15%
3/9/20	BP, Shell and Lightsource BP join forces on solar energy	Solar	-12.83%
2/12/20	BP sets ambition for net zero by 2050, fundamentally changing organisation to deliver	Sustainability Governance	-0.24%
12/5/19	Lightsource BP to accelerate global solar growth with further investment from BP	Solar	-0.69%
11/25/19	Lightsource BP pioneers UK's first night-time solar service	Solar	-2.65%
11/18/19	BP Chargemaster public charging points powering up to 1.5 million electric miles a week	EV / EV Charging	-1.92%
8/15/19	BP Chargemaster continues to grow, rolling out ultra-fast charging on BP forecourts across the UK	EV / EV Charging	0.46%
8/1/19	BP and DiDi join forces to build electric vehicle charging network in China	EV / EV Charging	0.47%

7/22/19	BP announces major expansion in renewable energy, combining biofuels and biopower with Bunge in Brazil to create a world-class bioenergy company	Biofuels	-0.92%
6/27/19	BP invests $30m in breakthrough technology to produce animal feeds from natural gas	Biofuels	-0.77%
3/26/19	BP commits $100 million to fund new emissions reductions projects	Sustainability Governance	-1.18%
3/13/19	BP and Environmental Defense Fund collaborate to reduce methane emissions	Sustainability Governance	2.26%
3/4/19	BP partners with Virent and Johnson Matthey on Virent's Bioforming® process for production of bio-paraxylene	Biofuels	0.48%
2/14/19	BP Energy Outlook 2019	Sustainability Governance	-0.07%
2/1/19	BP to support investor group's call for greater reporting around Paris goals	Sustainability Governance	4.09%
1/24/19	BP invests in PowerShare, one of China's leading electric vehicle charging platforms	EV / EV Charging	-2.49%
12/21/18	BP restructures U.S. Wind Energy business for growth	Wind	2.94%
10/9/18	BP and RocketSpace test advanced mobility solutions with global start-ups	EV / EV Charging	0.22%
9/25/18	BP and Johnson Matthey license innovative waste-to-fuels technology to biofuels producer Fulcrum BioEnergy	Biofuels	5.86%
6/28/18	BP to acquire the UK's largest electric vehicle charging company	EV / EV Charging	1.60%
4/16/18	BP sets out its commitment to a low carbon future	Sustainability Governance	-1.01%
2/20/18	BP Energy Outlook 2018	Sustainability Governance	-1.66%
1/30/18	BP invests in mobile electric vehicle charging company FreeWire to deliver rapid charging at retail sites	EV / EV Charging	-1.29%

Figure 5.2.12: BP's relevant announcements and CARs for event study, organized by descending dates.

The aggregate results for all seventy events are shown below, as well as the CAARs for each year and each classification.

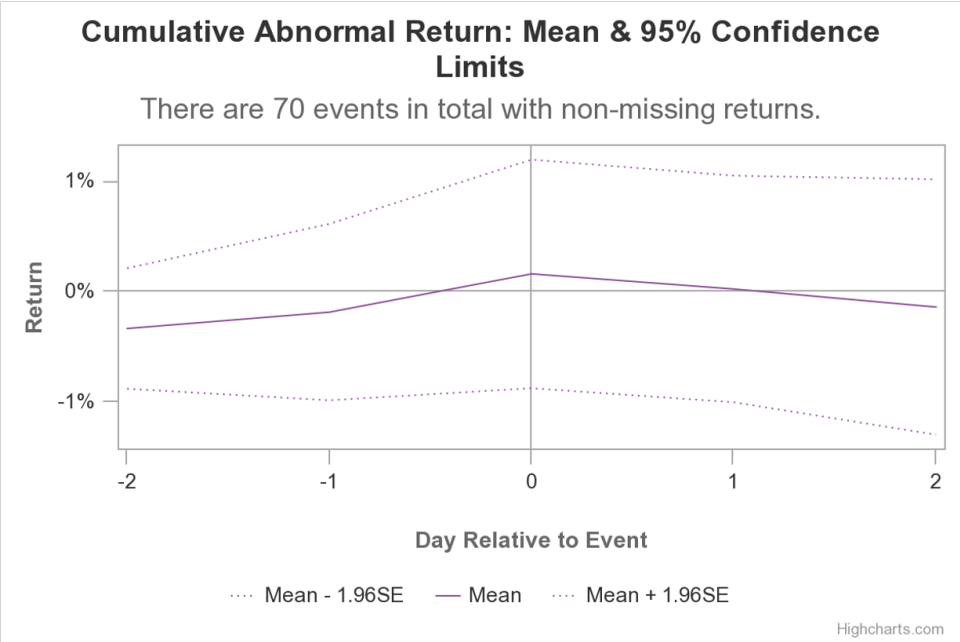

Figure 5.2.13: BP's cumulative abnormal returns summed on days relative to event.

$CAAR_{2018}$	**0.95%**
Count	*7*
StDev	*2.73%*
$CAAR_{2019}$	**-0.23%**
Count	*13*
StDev	*1.87%*
$CAAR_{2020}$	**-0.34%**
Count	*11*
StDev	*7.81%*
$CAAR_{2021}$	**-0.22%**
Count	*19*
StDev	*5.25%*
$CAAR_{2022/2023}$	**-0.31%**
Count	*20*
StDev	*5.07%*

Figure 5.2.14: BP CAARs, number of observations, and standard deviations for each year.

$CAAR_{EV\ /\ EV\ Charging}$	**-0.09%**
Count	*14*
StDev	*3.27%*
$CAAR_{Solar}$	**-0.24%**
Count	*12*
StDev	*5.25%*
$CAAR_{Wind}$	**0.56%**
Count	*8*
StDev	*6.53%*
$CAAR_{Biofuels}$	**1.47%**
Count	*10*
StDev	*4.27%*
$CAAR_{Hydrogen}$	**-1.52%**
Count	*10*
StDev	*8.50%*
$CAAR_{Carbon\ Capture}$	**-2.20%**
Count	*1*
StDev	*n/a*
$CAAR_{Sustainability\ Governance}$	**-0.54%**
Count	*15*
StDev	*2.42%*

Figure 5.2.15: BP CAARs, number of observations, and standard deviations for each classification.

Observing the aggregate results, the abnormal returns on the day the press release is published tend very close to zero per cent, which may indicate that the market generally believes these projects have a net present value close to zero. The year-over-year CAARs are relatively inconclusive, as they all remain between negative one and one per cent. Similar to Chevron's output, the market tends to view BP's biofuels projects as accretive events. Additionally, the data indicates that the market generally views hydrogen projects and changes in sustainability governance as dilutive events. Yet, the standard deviation for CAARs of hydrogen projects stands at a high figure of 8.50%, so this conclusion is not necessarily true for all hydrogen-related press releases.

TotalEnergies:

The chart below displays the relevant low carbon press releases for TotalEnergies between 2018 and 2023. Similar to BP, there are a significant number of press releases in the low carbon space, as TotalEnergies has established a strong presence in the renewable energy and emissions solutions industry.

Date of Event	Event	Classification	CAR(-2,2)
2/23/23	South Africa: TotalEnergies signs Renewable Power Purchase Agreements with Sasol and Air Liquide	Solar; Wind	0.48%
2/6/23	Denmark: TotalEnergies Obtains Two CO2 Storage Licenses in the Danish North Sea	Carbon Capture	-1.44%
12/1/22	Kazakhstan: TotalEnergies Implements its Energy Transition Strategy	Sustainability Governance	0.98%
11/22/22	Circular Economy: TotalEnergies and Air Liquide innovate to produce Renewable, Low Carbon Hydrogen at the Grandpuits Zero Crude Platform	Hydrogen	-0.52%
10/26/22	Brazil: TotalEnergies partners with Casa dos Ventos to jointly develop a 12 GW renewable energy portfolio	Solar; Wind	2.24%
10/4/22	Decarbonizing Heavy Industry: TotalEnergies and Holcim Join Forces to Study Solutions for First Carbon-Free Cement Plant in Belgium	Carbon Capture	6.14%
9/27/22	TotalEnergies Energy Outlook 2022	Sustainability Governance	-1.25%
8/31/22	Belgium: TotalEnergies selected to install 4,400 EV charging stations for electric vehicles in Flanders	EV / EV Charging	-3.58%
8/24/22	Australia: TotalEnergies, INPEX and Woodside Join Forces to Develop a Major Offshore CO2 Sequestration Project	Carbon Capture	3.32%
8/3/22	Floating Offshore Wind in France: TotalEnergies, Corio Generation and Qair Join Forces to Bid for Mediterranean Tender	WInd	-3.76%
6/14/22	India: TotalEnergies and Adani Join Forces to Create a World-Class Green Hydrogen Company	Hydrogen	-4.00%
5/25/22	United States: TotalEnergies acquires 50% of Clearway, the 5th largest U.S. renewable energy player	Solar; Wind	2.78%
5/13/22	TotalEnergies and Ørsted partner to participate in Dutch offshore wind tenders	Wind	5.73%

4/27/22	United States: TotalEnergies adds 4 GW to its Renewable Energy Portfolio with the Acquisition of Core Solar	Solar	0.16%
4/13/22	TotalEnergies and ENEOS join forces to Develop B2B Solar Distributed Generation across Asia	Solar	3.66%
3/24/22	Strategy, Sustainability & Climate Presentation: TotalEnergies reports on the progress made in 2021 and expands its ambition towards Carbon Neutrality	Sustainability Governance	0.44%
3/3/22	TotalEnergies Begins Producing Sustainable Aviation Fuel At Its Normandy Platform	Biofuels	-1.89%
2/28/22	United-States: TotalEnergies Wins Maritime Lease to Develop a 3 GW+ Offshore Wind Farm on the East Coast of New York and New Jersey	Wind	-7.60%
2/10/22	United States: TotalEnergies to Acquire SunPower's Commercial & Industrial Solar Business	Solar	-1.31%
2/2/22	TotalEnergies and Veolia Join Forces to Accelerate the Development of Biomethane	Biofuels	-1.07%
1/19/22	United Arab Emirates: TotalEnergies joins Masdar and Siemens Energy in initiative to drive green hydrogen development and produce Sustainable Aviation Fuel	Hydrogen	3.99%
12/21/21	TotalEnergies Launches the Largest Battery-Based Energy Storage Site in France	EV / EV Charging	-0.48%
12/7/21	EV charging stations: TotalEnergies to Install and Operate 800 New Charge Points in Ghent, Belgium	EV / EV Charging	1.59%
11/30/21	Taiwan: production start-up of the Yunlin offshore wind farm	Wind	1.68%
11/18/21	Australia: TotalEnergies Inks Two Partnerships to Develop Natural Carbon Sinks	Carbon Capture	-3.56%
11/10/21	TotalEnergies and Daimler Truck AG Partner to Develop Hydrogen Ecosystem for Transportation in Europe	Hydrogen	-0.50%
10/28/21	France: TotalEnergies Allocates €200 Million to Equip its Highway Service Stations with High-Power EV Charge Points	EV / EV Charging	-2.92%
10/20/21	TotalEnergies' Statement Following the Release of Global Environmental Change's Paper	Sustainability Governance	-2.59%
10/13/21	Floating Offshore Wind, United States: TotalEnergies and Simply Blue Group Launch TotalEnergies SBE US Joint Venture	Wind	0.67%
10/4/21	India: Adani Green Energy completes the acquisition of the 5 GW renewable portfolio of SB Energy India	Solar; Wind	4.18%
9/27/21	TotalEnergies and Safran Create a Strategic Partnership to Accelerate the Decarbonization of the Aviation Industry	Sustainability Governance	5.77%

9/14/21	TotalEnergies and Air Liquide Partner to Develop Low-Carbon Hydrogen Production in the Normandy Industrial Basin	Hydrogen	7.07%
9/7/21	Netherlands: TotalEnergies, Shell Netherlands, EBN and Gasunie Form Partnership to Develop the Offshore Aramis CO2 Transport and Sequestration Project	Carbon Capture	-0.13%
7/28/21	Singapore: TotalEnergies Acquires the Largest Electric Vehicle Charge Points Network	EV / EV Charging	4.61%
6/29/21	Accelerate the Transition Towards Electric Urban Mobility	EV / EV Charging	-5.72%
6/8/21	Electric Vehicles: TotalEnergies expands the charging network of the municipality of Amsterdam with 2,200 new EV charging points	EV / EV Charging	-1.72%
5/28/21	Total is Transforming and Becoming TotalEnergies	Sustainability Governance	2.56%
5/18/21	Air France-KLM, Total, Groupe ADP and Airbus Join Forces to Decarbonize Air Transportation and Carry Out The First Long-Haul Flight Powered By Sustainable Aviation Fuel Produced in France	Biofuels	-0.40%
4/29/21	Total Enters a 640 MW Offshore Wind Project Under Construction in Taiwan	Wind	1.72%
4/8/21	Total Begins Producing Sustainable Aviation Fuel in France	Biofuels	-4.90%
3/10/21	Orange signs a major green power purchase agreement with Total, which will develop 80 MW of solar farms in France to honor it	Solar	-2.49%
2/23/21	Total farms down 2 portfolios of renewable assets in France to Banque des Territoires and Crédit Agricole Assurances	Solar; Wind	11.89%
2/8/21	United Kingdom Offshore Wind: Total and GIG successful in securing seabed lease rights to jointly develop 1.5 GW offshore wind project	Wind	-3.37%
1/18/21	Total to Acquire from Adani a 20% Interest in the Largest Solar Developer in the World	Solar	-4.46%
12/15/20	Go-ahead from the Norwegian Authorities for the Northern Lights CO2 Sequestration Project	Carbon Capture	-4.79%
11/18/20	Electric Vehicles: Total to operate 2,300 EV charge points of the Bélib' network in Paris	EV / EV Charging	7.65%
10/30/20	Non-financial Reporting: Total discloses its first SASB report (Sustainability Accounting Standards Board)	Sustainability Governance	7.32%
10/15/20	India: Total strengthens its partnership with Adani in renewable energies	Solar	-2.83%
10/7/20	Renewables: Total enters the floating offshore wind sector in France	Wind	1.82%
9/29/20	United Kingdom: Total Acquires London's Largest Electric Vehicle Charge Points Network	EV / EV Charging	-5.72%

9/3/20	Groupe PSA and Total create "Automotive Cells Company", a joint venture dedicated to the manufacture of batteries in Europe	EV / EV Charging	4.83%
6/8/20	Total joins the “Getting to Zero Coalition” to Contribute to Shipping Industry’s Decarbonization	Sustainability Governance	1.79%
5/15/20	Historic investment decision for transport and storage of CO_2 (Northern Lights Project)	Carbon Capture	1.60%
5/5/20	Total adopts a new Climate Ambition to Get to Net Zero by 2050	Sustainability Governance	1.22%
4/22/20	France: Total Wins Over 135 MW of Projects in the Latest National Solar Tender	Solar	0.99%
3/20/20	Renewables: Total Expands in Wind Power in France with the acquisition of Global Wind Power France	Wind	23.38%
3/12/20	Total to Build the Largest Battery-based Energy Storage Project in France	EV / EV Charging	-12.14%
2/11/20	Spain: Total to Enter into the Solar Market with a pipeline of 2 GW of projects	Solar	-2.43%
1/22/20	Electric Vehicles: Total will install and operate up to 20,000 new EV charging points for ‘Metropolitan Region Amsterdam Electric’	EV / EV Charging	-3.65%
1/6/20	Svante, LafargeHolcim, Oxy Low Carbon Ventures and Total launch study for commercial-scale carbon capture and end-use at U.S. plant	Carbon Capture	1.59%
11/22/19	Renewables: Total Continues to Expand its Footprint in Southeast Asia in Distributed Solar	Solar	-1.35%
11/8/19	2019 Climate Report: Total Reviews Its Membership in Industry Associations in Line with Their Climate Stance	Sustainability Governance	-1.46%
10/24/19	Total dedicates its $400 million global venture fund to Carbon Neutrality	Sustainability Governance	1.03%
10/8/19	Total launches construction of its third solar power plant in Japan	Solar	0.31%
9/16/19	Total and Envision join forces to capture the fast-growing distributed solar energy market in China	Solar	3.14%
7/3/19	Total Starts Up the La Mède Biorefinery	Biofuels	-0.98%
6/3/19	Total Starts Up its Second Solar Power Plant in Japan	Solar	-1.12%
4/4/19	Saft joins forces with the Chinese Group Tianneng to grow in China and scale up its e-mobility and energy storage businesses	EV / EV Charging	0.99%
2/18/19	France: Total, Ørsted and Elicio join forces to bid for a wind farm offshore Dunkirk	Wind	1.77%
12/5/18	Electric Mobility & Innovation: Total Launches a Pioneering Line of Fluids for Electric and Hybrid Vehicles	EV / EV Charging	1.63%

9/20/18	Electric Vehicle Charging Solutions: Total Acquires G2mobility and Forms Partnership with Nexans	EV / EV Charging	3.38%
3/27/18	Total becomes a founding partner of the Cathay Smart Energy Fund to invest in the new energy sector in China	Sustainability Governance	2.08%

Figure 5.2.16: TotalEnergies' relevant announcements and CARs for event study, organized by descending dates.

Shown below are the aggregate results of TotalEnergies' event studies, as well as the CAARs for each year and each classification.

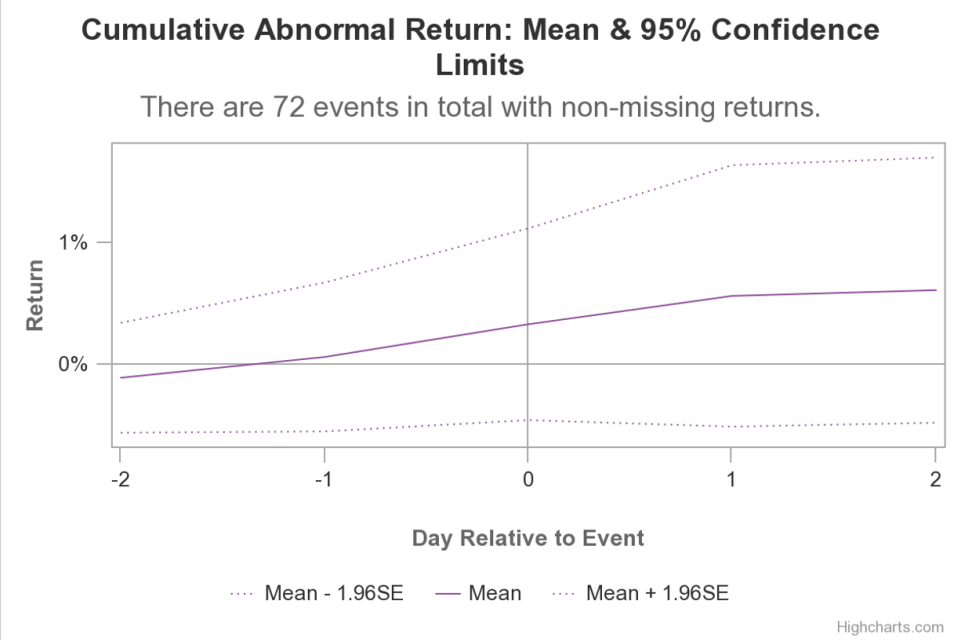

Figure 5.2.17: TotalEnergies' cumulative abnormal returns summed on days relative to event.

$CAAR_{2018}$	**2.36%**
Count	*3*
StDev	*0.91%*
$CAAR_{2019}$	**0.26%**
Count	*9*
StDev	*1.61%*
$CAAR_{2020}$	**1.29%**
Count	*16*
StDev	*7.74%*
$CAAR_{2021}$	**0.37%**
Count	*23*
StDev	*4.27%*
$CAAR_{2022/2023}$	**0.17%**
Count	*21*
StDev	*3.43%*

Figure 5.2.18: TotalEnergies CAARs, number of observations, and standard deviations for each year.

$CAAR_{EV\ /\ EV\ Charging}$	**-0.75%**
Count	*15*
StDev	*5.09%*
$CAAR_{Solar,\ Wind}$	**1.33%**
Count	*27*
StDev	*5.78%*
$CAAR_{Biofuels}$	**-1.54%**
Count	*5*
StDev	*1.78%*
$CAAR_{Hydrogen}$	**1.21%**
Count	*5*
StDev	*4.33%*
$CAAR_{Carbon\ Capture}$	**0.34%**
Count	*8*
StDev	*3.59%*
$CAAR_{Sustainability\ Governance}$	**1.49%**
Count	*12*
StDev	*2.83%*

Figure 5.2.19: TotalEnergies CAARs, number of observations, and standard deviations for each classification.

Similar to BP, the aggregate results indicate that TotalEnergies' low carbon press releases have a cumulative abnormal return that tends slightly above zero per cent. This indicates that the company's repositioning within the energy transition has not necessarily created nor destroyed

significant amounts of value for shareholders. Unlike BP, the market appears to value TotalEnergies' projects in the solar and wind space positively, while projects in the biofuels space have a -1.54% CAAR with a relatively low standard deviation. Similar to BP, the year-over-year CAARs are fairly inconclusive, and the changes in sustainability governance, mainly being capital expenditure commitments and annual climate reports, result in a positive CAAR.

Takeaways

These results, as mentioned above, would require further studies to solidify; however, there are a few important conclusions that can drawn. It is evident that the oil majors' activity in the low carbon space does not create or destroy significant amounts of value for shareholders, as the cumulative abnormal returns lie between negative one and one per cent on the day of the event and the two days before and after the event for each company except Shell. Shell's cumulative abnormal returns, restricted to 2022 and 2023 event studies, are far more susceptible to other idiosyncratic and industry-wide risks due to the limited data sample. Further, the impact of different types of activities, namely carbon capture, biofuels, hydrogen, solar and wind, electric vehicle batteries and charging, is different for each major and likely depends on the respective positioning within the energy transition.

VII. DISCUSSION

The fundamental premise of the energy transition is to limit greenhouse gas emissions, thus mitigating future increases in global temperature levels. A key finding from this study is that, while progress is observable, the net zero commitments of oil and gas majors are relatively 'toothless.' The five majors being analyzed are all relatively on pace to reach net zero operating emissions by 2050. However, the majority of their emissions come from consumer use (Scope 3), and a clear roadmap to reduce these emissions has not been thoroughly established. With global carbon prices forecasted to converge and rise rapidly, the profitability of oil and gas majors will likely be conditional to global climate policy.

Examining the low carbon strategies of each major, this study finds that the U.S. majors – ExxonMobil and Chevron – have generally invested in mitigative technologies while the European majors – Shell, BP, and TotalEnergies – have invested in a mix of proactive and mitigative technologies. ExxonMobil and Chevron have organically integrated carbon capture and storage, hydrogen, and biofuels into their operations while refraining from major investments in renewable power – solar and wind. Shell, BP, and TotalEnergies have invested organically and inorganically in a diversified portfolio of low carbon technologies, deploying a significant portion of their capital expenditures into solar, wind, electric vehicle charging and convenience sites as well as carbon capture and storage, hydrogen, and biofuels. These results indicate that the activity of the U.S. majors lags that of the European majors.

The event studies indicate that public markets – using the S&P 500 index – tend to value low carbon activity with a net present value close to zero. From the perspective of shareholders, this entails that the implementation of energy transition strategies does not necessarily have an

accretive or dilutive effect on the value of each company. Given that crude oil and natural gas have been extremely volatile within the timeframe of these event studies, one could affirm these results by using the oil and gas industry index as a proxy for public markets and regressing the betas and alphas of each company from there.

In conclusion, the results of this study contribute to the analysis of the following questions about oil and gas majors: *Are the net zero emissions targets feasible?*; *Can a net zero oil and gas company be profitable?*; *What might the future mix of energy sources look like for oil and gas companies?*; and *How do public markets value energy transition activities?* While it is nearly impossible to produce a concrete answer to any of these questions, this paper aims to provide a framework of analysis based on the data currently available.

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