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MEASURING TRANSITION RISK IN THE ENERGY SECTOR: EVIDENCE OF A GREEN FACTOR INFLUENCE ON STOCK RETURNS

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Abstract

Energy companies are heavily exposed to carbon transition risk as the global system fights to transform the economy from reliance on fossil fuels to cleaner energy. At the same time, the energy sector is operating in a complex scenario with net zero emissions commitments that need to be compatible with the security of supply and affordability of the energy sources. Traditionally, investments in hydrocarbons have delivered higher returns than investments in low-carbon technologies. Investors and energy companies therefore need to decide whether to be clean and earn low returns or invest in a carbon-intensive business that provides higher returns. The measurement of transition becomes a crucial component of the investment decision process.

We aim to measure whether stock returns reflect investors´ concerns regarding transition risk in North America and Europe. For this purpose, we extend the benchmark factor-based asset pricing models and construct a green factor based on long-short positions with low versus high-emissions-intensive corporations producing energy. We find that the green factor delivers positive risk-adjusted returns in both of the geographical areas considered. Furthermore, we explore the effect of the green factor in explaining stock returns and find that a) it has a negative and significant effect in the energy sector and b) it exerts a positive and significant effect in the utility sector. An alternative green factor is constructed with zero-carbon emitters from renewable energy producers. Reported results reveal that this contributes to the explanation of returns and delivers an excess return that cannot be explained by the Carhart (1997) four-factor model.

Our findings align with the view that investments in low-emitting technologies provide a hedge against carbon transition risk and investors´preferences for cleaner energy firms and increase the cost of capital equity of higher emissions-intensive energy companies.

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1 INTRODUCTION

1.1 Motivation and purpose

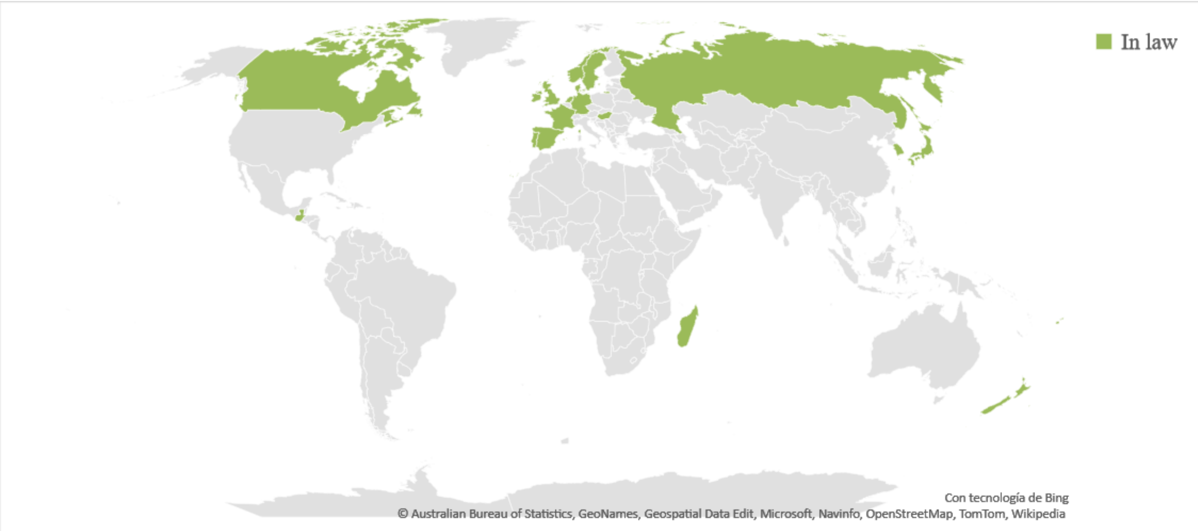
One of the most relevant challenges for our present and near future is how to cope with the consequences of climate change. The Intergovernmental Panel on Climate Change (IPCC), the scientific body established in 1988 and endorsed by the United Nations, has been publishing assessment reports emphasising that climate change is a challenge with global consequences which demand international cooperation and mitigation efforts.

According to the IPCC, climate change could cause a variety of ecological, physical, and health impacts, including extreme weather events such as floods, droughts, storms, and heatwaves, as well as rising sea levels, changes in crop growth, and disruptions to water systems. The primary cause of climate change is the release of greenhouse gases (GHG), particularly carbon dioxide (CO_2), resulting from human activities.[1] A detailed analysis of the potential impacts of climate change and the link between global temperatures and greenhouse gas concentrations, especially CO_2, was reflected in the IPCC Fifth Assessment Report (IPCC, 2014) which provided the scientific background for the 2015 Paris Agreement target of limiting the temperature increase well below 2ºC, with the ambition of limiting it to 1.5ºC, compared to pre-industrial levels. This agreement, reached in the Conference of the Parties (COP26) of the United Nations Framework Convention on Climate Change, represents the most ambitious commitment since the 1997 Kyoto Protocol, whereby developed country signatories legally committed themselves to emission reduction targets.

[1] As atated by IPCC, the main greenhouse gases (GHG) are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2 O), and fluorinated gases (F-gases). Aggregated GHG emissions are stated in CO_2-equivalent (CO_2-eq).

Article 4.1 of the Paris Agreement emphasizes the importance of attaining a state of net zero emissions, whereby the amount of GHG released into the atmosphere by human activity is balanced by the amount removed by natural processes, such as absorption by trees or other natural "sinks". This balance must be achieved within the second half of this century. Now, however, as provided in Figure 1-1, the country-level commitments differ in terms of their implementation. [2]

Figure 1-1
Net zero commitments in law



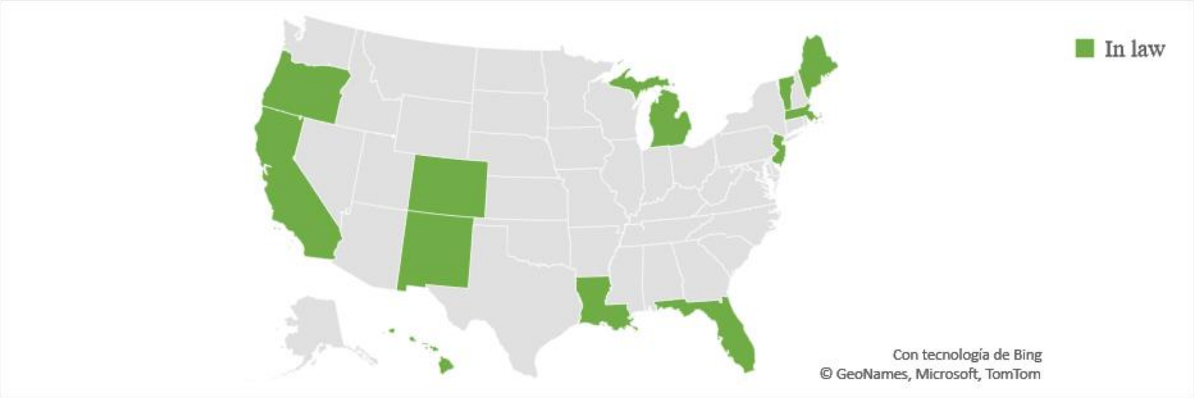
Source: Net Zero Tracker. Data downloaded as of June 2022.

Countries that represent only 10% of global GDP and 5% of global emissions have strong commitments and clear plans to achieve this goal, evidenced by their incorporation in law. Considering only the G20 countries, just the following six countries have committed by law to meet their net zero targets: Canada, France, Germany, Japan, Russian Federation, and the UK.

[2] Oxford University based on Net Zero Tracker, available at https://www.ox.ac.uk/news/2021-11-01-80-world-economy-now-aiming-net-zero-not-all-pledges-are-equal.The Net Zero Tracker is a global initiative to quantify the effectiveness of global net zero targets. Database available at https://zerotracker.net/analysis

It is also worth noting that the European Union has also approved a net zero law by 2050 and in the case of the USA, net zero laws have been approved by only 14 states, including California, Colorado, Florida, Massachusetts, New Mexico, New York, and Washington, as reflected in Figure 1-2.

Figure 1-2
USA net zero commitments by state laws



Source: Net Zero Tracker. Data downloaded as of June 2022.

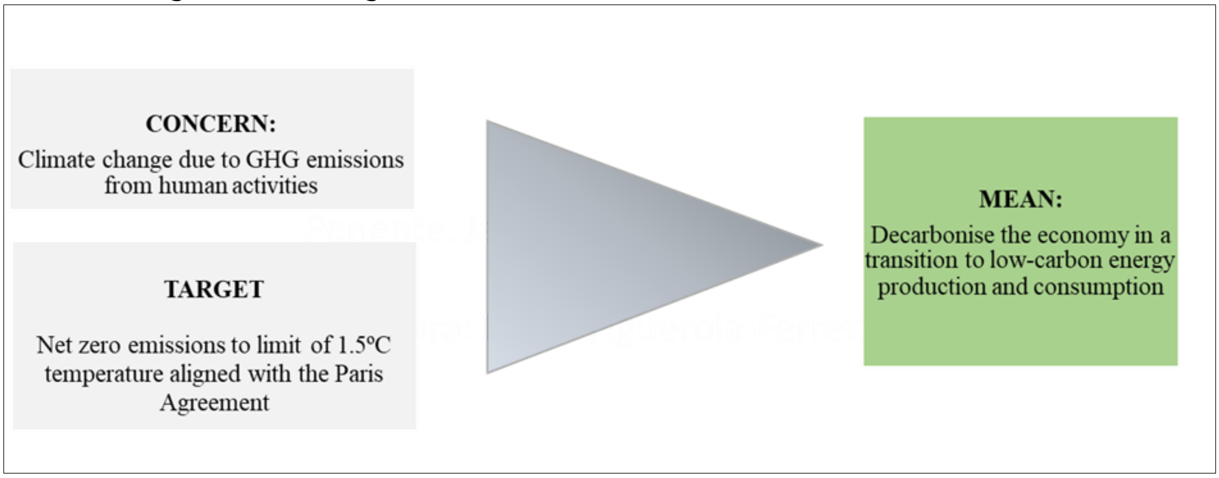
Furthermore, the speed required to reach the global warming limit of 1.5°C, without sacrificing economic growth, is another challenge. To predict the amount of CO_2 emissions our atmosphere could absorb, the IPPC Sixth Assessment Report, Working Group I (IPCC, 2021), estimates the remaining "carbon budget" depending on the likelihood of limiting global warming to 1.5ºC. If considered a 50% chance, the world could emit 500 Gt CO_2 from the beginning of 2020. This is equivalent to approximately 9 years of global CO_2 emissions if they remain at current rates and do not start declining.

A review of the most recent data on GHG emissions, published in the IPCC Sixth Assessment Report, Working Group III (IPCC, 2022), corresponding to 2019, shows that for the last 30 years, the energy system has been the single largest contributor to global GHG emissions. There are two fundamental areas in which we need to make progress in reducing GHG emissions. The immediate problem is how to tackle energy production and consumption (which affects power for electricity and heating), industrial activities, transport, and buildings, given that they collectively comprise 78% of total GHG emissions. The second is how to reduce emissions due to agriculture, forestry, and other land use (the AFOLU sector), which represents 22% of total GHG emissions.

Focusing our lens on 2019 with the figures provided by IPCC (2022), of the 59 GtCO2eq of GHG emitted, 33% (20 GtCO2eq) came from the energy sector (electricity, heat and other energies), 24% (14 GtCO2eq) from industry, 22% (13 GtCO2eq) from AFOLU, 15% (8.7 GtCO2eq) from transport and 6% (3.3 GtCO2eq) from buildings.

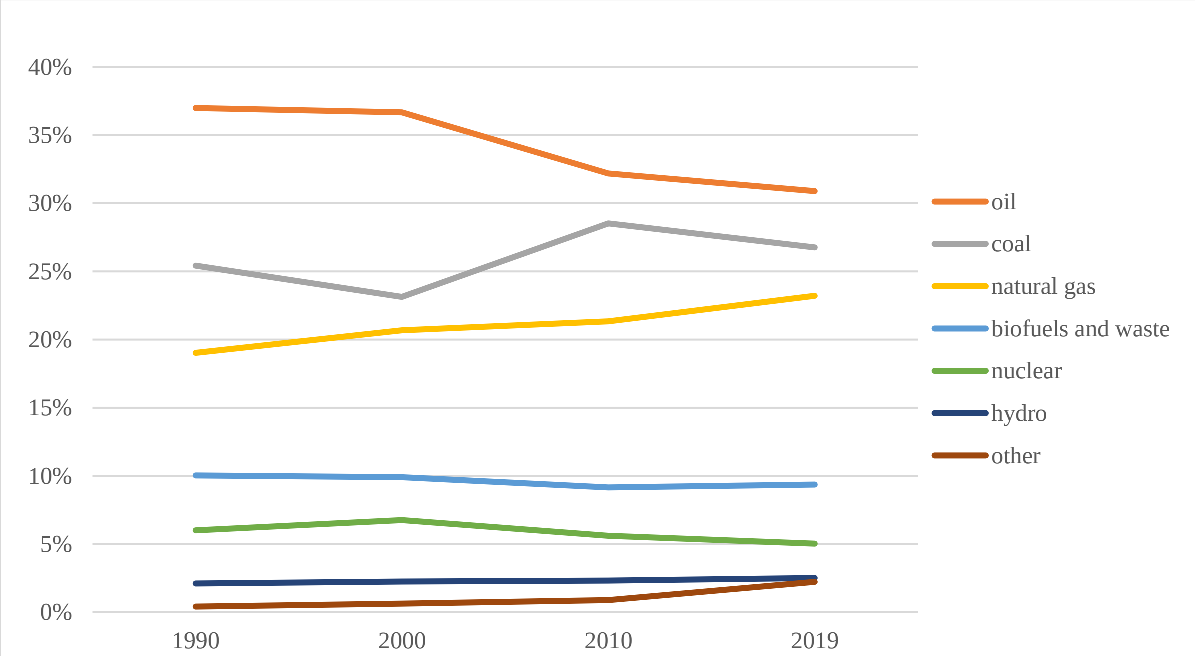
In 2019, the energy sector was the largest contributor to global GHG emissions. However, if we classify the emissions from this sector as indirect emissions (Scope 2) and allocate them to consuming sectors, we can identify the role of the final demand-side of energy. As a result, the industry sector's emission share increases to 34%, while the buildings sector's emission share increases to 16%. Based on these interactions, Figure 1-3 shows the clear linkage between climate change concerns and the profound changes needed in the way we produce and consume energy to reach net zero emissions.

Figure 1-3
Climate change concern, target, and mean



Moving from the 59 $GtCO_2eq$ of GHG emitted in 2019 to reaching net zero emissions in 2050 will require significant changes in the business models of many sectors and energy companies will need to play a significant role in providing an energy mix with a much lower carbon footprint. As reflected in Figure 1-4, the Global Energy Supply report (IEA, 2021a) by the International Energy Agency (IEA) confirms that over the past 30 years, fossil fuels - including oil, coal, and natural gas - have been the primary sources of energy in the global energy mix

Figure 1-4
World energy supply trend by source 1990-2019



Source: IEA (2021a)

Our motivation is to explain how the transition to a lower-carbon economy may impact the financial performance of the energy sector and particularly oil and gas companies, given their relevance in the global energy supply mix.

In line with the country-level net zero commitments, the response by oil and gas companies is evolving at different speeds. Some are establishing concrete plans and strategies to reach their net zero targets, while others are still preparing for their transition. Some companies have begun to diversify their business strategies, divesting their higher-intensive emission assets, or investing in lower-carbon energy activities. The transition brings both risks and opportunities to the financial performance, and it affects how these firms will fund their future asset mix.[3]

This pathway appears to be necessary for oil and gas companies' long-term survival. Developing a credible narrative about their corporate purpose in a changing energy market is a challenge that needs a response from all stakeholders. If this scenario appears to be complex enough, the net zero transition should also be able to provide security of energy supply as well as affordability. Therefore, oil and gas companies cannot operate in isolation from these global challenges.

Energy security, as defined by the IEA, encompasses two objectives: ensuring uninterrupted access to energy sources at affordable prices. Long-term energy security is primarily concerned with making timely investments to meet economic and environmental demands, while short-term energy security focuses on the energy system's ability to respond quickly to sudden shifts in supply and demand.[4]

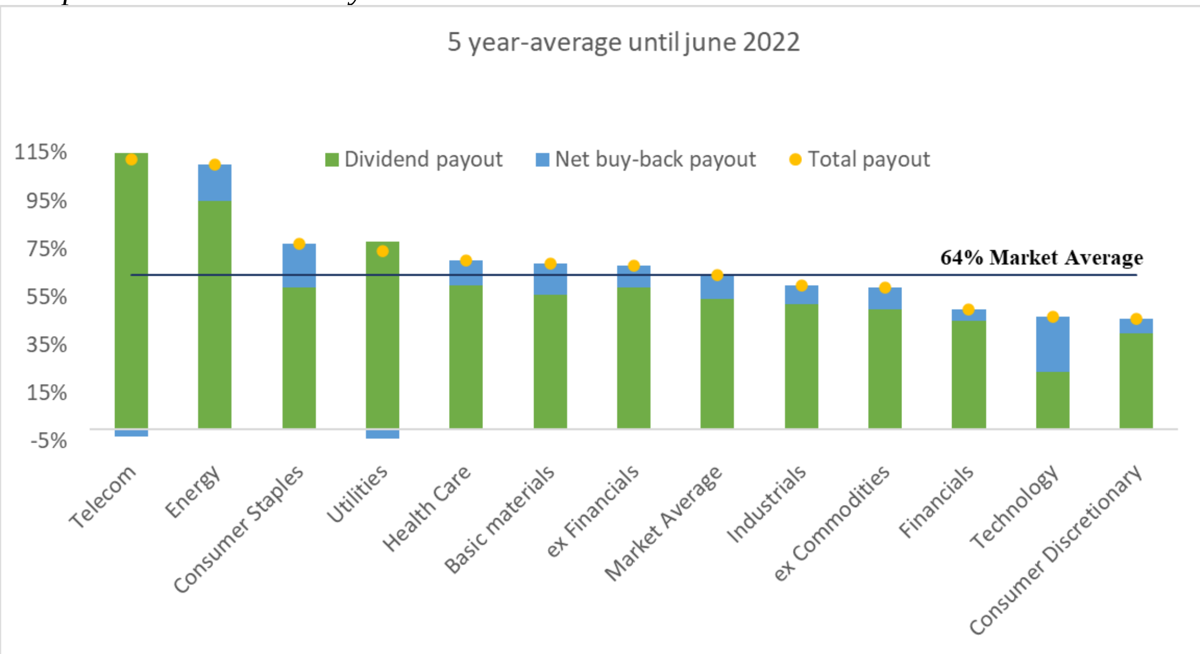
In this complex scenario of net zero commitments, security of energy supply and affordability, both energy companies and their investors are facing a dilemma in terms of their expected financial returns. Energy companies have traditionally rewarded investors with higher dividend payouts and share buy-backs than other sectors on average, and the transition to lower-carbon energy businesses can certainly be profitable, but their returns are generally lower than for hydrocarbons. This is a factor that can generate some concern in the marketplace. Oil and gas is a high-risk industry, which can be a high-return business when the exploration of fields results in the successful discovery of hydrocarbons and when positive economics support

[3] IEA (2020) develops different scenarios and strategies about the Oil and Gas Transitions.
[4] IEA definition about energy security is available at https://www.iea.org/topics/energy-security

their development, production, and commercialisation; a low-carbon business, however, is a lower-return business, such as in the case of renewables.

As shown in Figure 1-5, energy companies (excluding utilities) operating in the European market have provided investors with a dividend payout ratio averaging close to 95% over the past five years. Moreover, when considering net share buybacks close to 110%, it is the largest total payout ratio, comparable only to the telecom sector and well above the market average of 64%. The payout ratio of the utility sector is close to 75%.

Figure 1-5
European stock market: Payout ratios

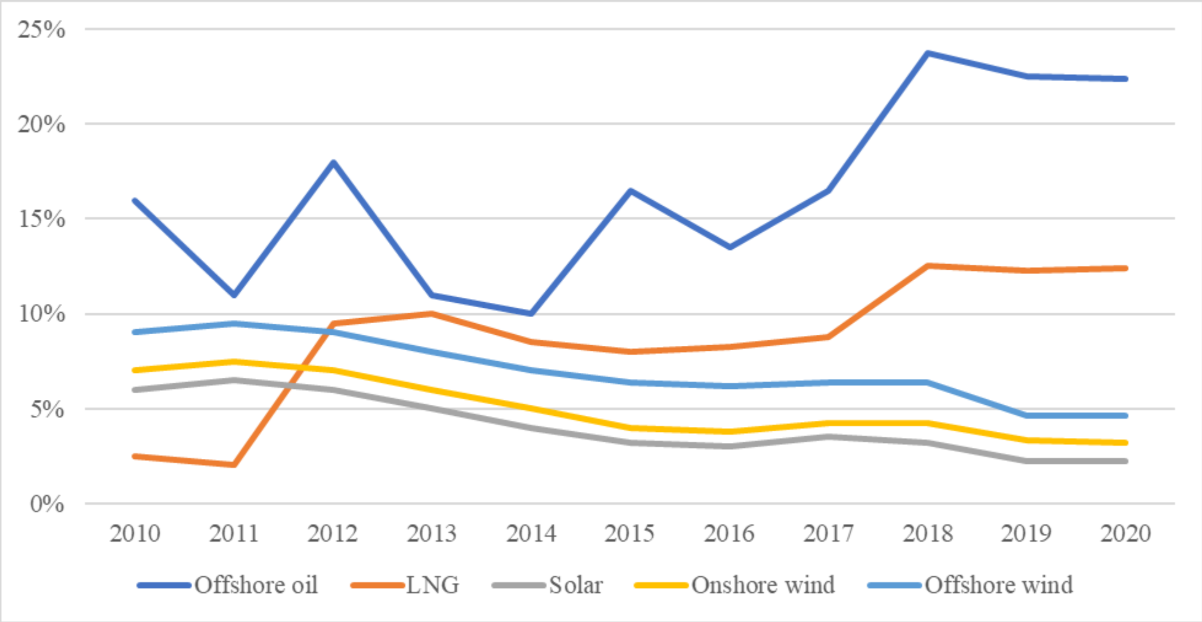


Source: Goldman Sachs (2022a)

On the corporate side, Figure 1-6 depicts a substantial gap in the return on investments between the top oil and gas, and that from renewable projects, as measured by their internal rate of return (IRR) by the year of their project sanction. During the period 2010-2020, a significant IRR median difference exists that reaches 12 percentage points in favour of the oil and gas projects. Oil offshore projects yield an IRR of 17%, and LNG of 9%, while combined offshore wind, onshore wind, and solar photovoltaic are approximately 4%.

Figure 1-6

IRR: Oil and gas versus renewable energy projects



	Offshore oil	LNG	Solar	Onshore wind	Offshore wind
Median 2010-2020	17%	9%	4%	4%	6%

Source: Goldman Sachs (2022b)

Investors looking for their optimal risk-return profile may efficiently diversify their portfolios by choosing their best-in-class companies producing energy and, between them, oil and gas firms or other kinds of companies, such as power utilities or renewables, producing energy with higher or lower carbon emissions and commitments to reach net zero targets. In their portfolio allocation, investors need to be conscious that returns may be lower on those companies with low-carbon energy businesses but that these are necessary to decarbonise the economy.

Because of all the above-mentioned factors, a new risk-return profile may emerge to differentiate companies, and investors may be willing to reward them if they are likely to succeed in their energy transition. This is also the context in which to identify whether investors make their decisions regarding energy companies while taking into account a carbon-transition risk as a new kind of financial risk.

Table 1-1
Motivation and purpose summary

In summary, our motivation is to provide some insight that can help to resolve the following questions:

(1) Are investors willing to support energy companies to develop lower carbon businesses in the context of carbon transition risks delivering lower expected returns?

(2) Are energy companies pursuing optimal strategies from the financial and environmental perspective when they invest?

Given the above statements, our purpose is to identify and measure any existing "green factor", or, conversely, any "carbon transition risk" that reflects the transition of energy companies to a low-carbon ("green") business; we also aim to determine whether that green factor may explain the stock returns for energy companies and particularly oil and gas companies.

1.2 Aim and research questions

We embrace the challenge of shedding light on the implications that a transition to a lower-carbon economy is potentially already affecting the energy sector and specifically companies in the oil and gas sector. Based on the definition of transition risk, we intend to gain insights into whether it is still perceived by the financial markets as a long-term risk or whether there has been a shift that has accelerated in recent years, which is translating this into the oil and gas sector share price performance.

To the best of our knowledge, our study is a novel approach to seeking evidence regarding the potential impact of carbon transition risk in the energy sector and around the oil and gas companies, represented by the largest firms in the developed economies of Europe and North America.

We will base our analysis on the company and sector level, and we are uncertain as to what we may find. As explained in more detail in the following section, several indications led us to expect positive results on our preliminary hypothesis, which we formulate as follows:

> Hypothesis 1 (null hypothesis): Financial markets are already pricing carbon transition risk to the oil and gas sector which is reflected in higher stock returns.
>
> Hypothesis 2 (alternative hypothesis): Financial markets are reflecting a preference for cleaner or green energy stocks and rewarding them with a higher stock return while carbon transition risk in turn reflects lower stock returns and higher cost of equity capital for oil and gas companies.

We summarise our research process in the following table.

Table 1-2
Research process

Aim	• Quantify carbon transition risk in the energy sector, and in more detail, oil and gas companies. • Our focus will be in companies from Europe and North America (USA and Canada).
Additional objectives	• Analyse the political and regulatory response to the transition to a low-carbon economy. • Assess the impact of carbon transition on the risk-return profile of investors and oil and gas companies, which influences on their cost of equity capital. • Extract signals if the speed to a lower carbon profile may improve their stock returns.
Research questions	• With the progressive assessment of carbon transition risk: 1- Can we explain the share price return of oil and gas companies in Europe and North America through the existence of a green transition factor? 2- Can stock price returns for companies involved in clean energy sources be explained by a green transition factor?

Acknowledging carbon transition risk is a global challenge, our area of concern is to analyse its impact on the financial performance of the leading oil and gas listed companies in

Europe and North America, given their significant contribution to GHG emissions and the technological difficulties underlying the transition to lower carbon activities.

In this context, our research aim is to quantify the effect of the carbon transition risk on corporate performance. This includes measuring the impact of new technologies on oil and gas companies. In doing so, we will measure the impact of carbon transition risks on the risk-return profile of their shareholders and therefore determine the way in which their preferences may influence the cost of equity capital of these companies.

Our research also analyses the relevance of increased political response and support from governments and policymakers to technological developments oriented to thrive in the transition to a lower-carbon economy.

Table 1-3
Research questions

Our research questions focus on the recent progressive assessment of carbon transition risk:

(1) Can we explain the stock price return of oil and gas companies in Europe and North America through the existence of a green transition factor?

(2) Can stock price returns for companies involved in clean energy sources be explained by a green transition factor?

In our view, oil and gas companies are striving to respond to investor demand for higher returns while also adjusting their business models to align with climate goals. To explore inclusive solutions and forward-looking orientation, as part of our research, we also intend to extract potential signals whether the speed of change in oil and gas businesses' transition to a lower carbon profile may ultimately increase their financial performance and valuation.

Energy transition represents a global challenge that requires coordinated direction and a common course of action to be successful. In the words of Dr. Fatih Birol, IEA Executive

Director, (IEA, 2020) “No energy company will be unaffected by clean energy transitions. Every part of the industry needs to consider how to respond. Doing nothing is simply not an option” (p.1).[5]

1.3 Objectives

The main objective of this thesis is to quantify the carbon transition risk affecting oil and gas companies by determining the factors arising or becoming more relevant based on academic literature and management practice.

We will identify a process to select the scope and boundaries of the energy sector and certain indicators, such as the carbon intensity per unit of energy produced, that have not yet been fully considered in the literature; thus, this study will contribute to further research.

Therefore, we intend to explore potential indicators of the speed of companies in adapting to the energy transition by comparing different business models within the energy sector in a broad sense (oil and gas companies and cleaner energy producers) and the impact of new technologies applied and forecasted for energy generation and consumption under the horizons 2030 and 2050. New technologies include, for example, renewable energies (wind and solar), renewable hydrogen, or carbon capture, utilisation, and storage (CCUS) technologies.

Our analysis shed light on the capital allocation process of energy corporates. We address whether strategies towards shareholders' remuneration or expanded capital expenditures can boost the energy transition and contribute to reducing carbon transition risks. This aims to provide insights into the dilemma of selecting between low-carbon businesses with lower returns and traditional oil and gas businesses that also have higher market average payouts.

[5] IEA (2020, January 20) [press release]. *Oil and gas industry needs to step up climate efforts now*. Available at https://www.iea.org/news/oil-and-gas-industry-needs-to-step-up-climate-efforts-now

The results of the research are intended to contribute to an explanation of the extent to which management decisions, that are likely to affect carbon transition risk, lead to higher corporate performance. This is a novel approach for shedding light on transition risk.

1.4 Content and structure

The rest of the thesis is structured as follows. Chapter 2 provides the background, setting the scene for the research, which covers four parts: (a) the role of energy in climate change; (b) the relevance of the institutions in the fight against climate change; (c) the identification of the risks associated with climate change to frame the relationship between financial markets and the energy sector; and (d) the progressive awareness of carbon transition risk affecting the energy sector.

Next, Chapter 3 presents the state of the art, which is divided into two sections: (a) the literature review related to our research; and (b) the transition risk drivers affecting equity markets, mapping the evolution and outlook for climate-friendly investments, technology and policy regulation in the USA and European Union. This section ends with a preliminary assessment of the transition risk of the energy sector by the stock market.

Chapter 4 describes the analytical process for the data collection and the data sources, including a description of the proxy for carbon transition risk, which comprises the basis for our green factor.

In Chapter 5, the methodology is presented, as well as the data for the construction of our green factor to explain the energy portfolio returns. Subsequently, Chapter 6 presents the empirical results, and Chapter 7 provides the discussion. Finally, Chapter 8 explains the conclusions derived from the results, details the main contributions this study makes to the literature, and highlights recommendations for future research areas.

2 SETTING THE SCENE

2.1 Contextual information on energy and climate change

Energy is a highly relevant factor for human development and economic growth. Providing secure and affordable energy is essential to support economic and social progress and build a better quality of life. This is true everywhere, but especially in developing countries, where access to energy is still insufficient.

While living standards have increased and people have been living longer and healthier lives, accelerating demand for energy has resulted in a growing threat to the stability of the earth's climate. A key challenge is to fulfill the increasing energy demand while ensuring safety and environmental responsibility.

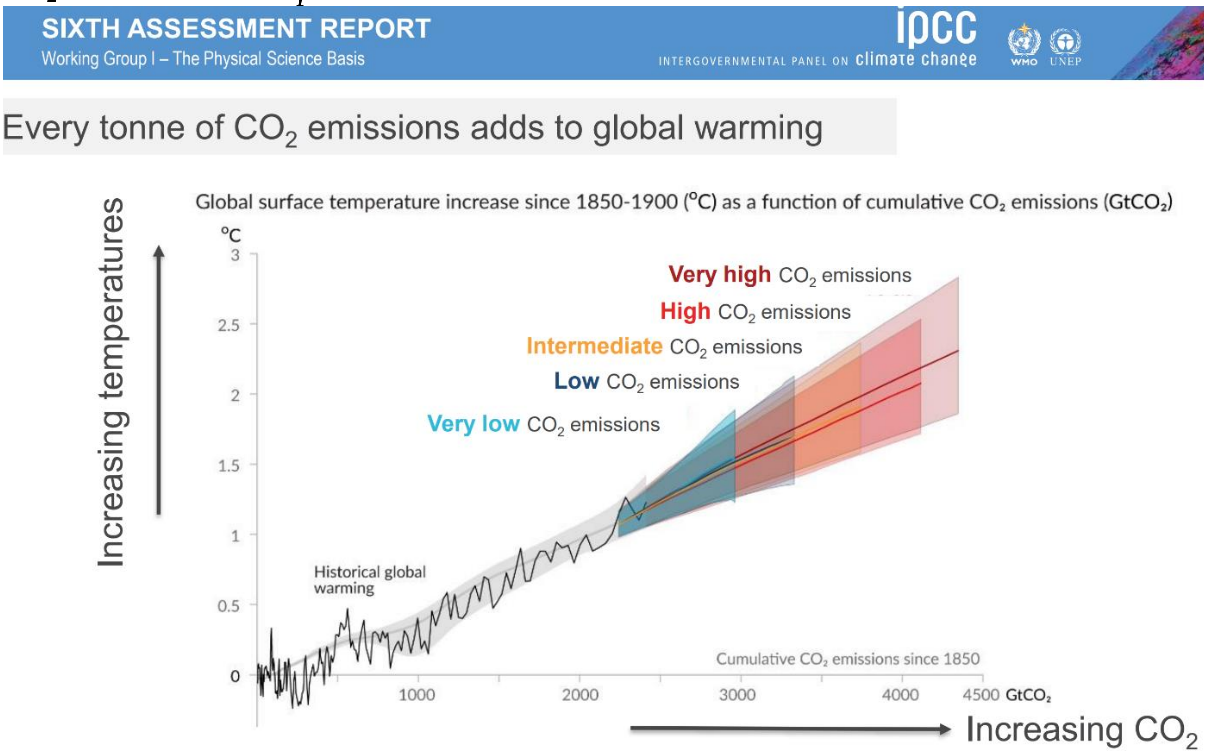
Though it has been a matter for debate for some decades, there is now a widespread consensus among 90%–100% of publishing climate scientists that human behaviour is causing global warming (Cook et al. 2016).

In this line of research, the sixth Report of the Intergovernmental Panel on Climate Change, Working Group I (IPCC, 2021), presented the first part of its global assessment of climate change in August 2021. IPCC is the United Nations body for assessing the science related to climate change. The latest report acknowledges the undeniable impact of human activities that have led to a rise in temperature in the atmosphere, oceans, and land. The evidence of extreme weather events such as heatwaves, heavy rainfall, droughts, and tropical cyclones has also become more compelling since the last report.

According to the report, human GHG emissions have caused around 1.1°C of warming from 1850-1900. It also predicts that the global temperature will likely reach or surpass a 1.5°C increase in the next two decades. Figure 2-1 shows the highly probable range of global surface temperature projections through the shaded areas, while the median estimate is shown by the central lines. The scenarios considered in the graph range from very low to very high emissions and cover the period from 2020 to 2050 in terms of cumulative CO_2 emissions.

Figure 2-1

CO_2 emissions and temperature increase



Source: IPCC (2021)

Another key physical science finding from the report is that, among GHG and air pollutants, CO_2 is the primary driver of climate change.

At the same time, the report provides signs of hope since human actions still have the potential to determine the future course of the climate by sustained reductions in GHG emissions and reaching net zero CO_2 emissions.

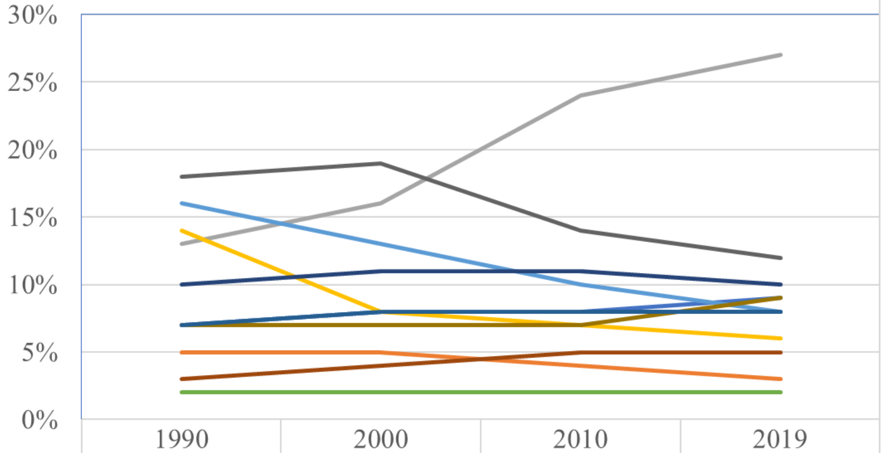
To understand how we have arrived at this point, we examine the progression of GHG emissions from 1990, taking into account the regions of the world and the various sectors that contribute to these emissions.

a) World regions and GHG emissions:

As depicted in Figure 2-2, the most significant share increase comes from Eastern Asia (China, North and South Korea, and Mongolia), while material share reductions come from Eastern Europe & West-Central Asia, Europe, and North America. The leading factor behind the increase in energy consumption and CO_2 emissions worldwide has been GDP per capita, which has grown almost in conjunction until 2015, after which a modest decoupling trend emerged. Nevertheless, the reduced energy use per unit of GDP in nearly all regions and significant decarbonisation of the energy sector in North America, Europe, and Eastern Europe & West Central Asia have been the primary factors counteracting the increase in emissions.[6]

Figure 2-2

World net GHG emissions by regions 1990-2019



	1990	2000	2010	2019
Africa	7%	8%	8%	9%
Australia, Japan and New Zealand	5%	5%	4%	3%
Eastern Asia	13%	16%	24%	27%
Eastern Europe and West-Central Asia	14%	8%	7%	6%
Europe	16%	13%	10%	8%
International shipping and aviation	2%	2%	2%	2%
Latin America and Caribbean	10%	11%	11%	10%
Middle East	3%	4%	5%	5%
North America	18%	19%	14%	12%
South-East Asia and Pacific	7%	7%	7%	9%
Southerm Asia	7%	8%	8%	8%

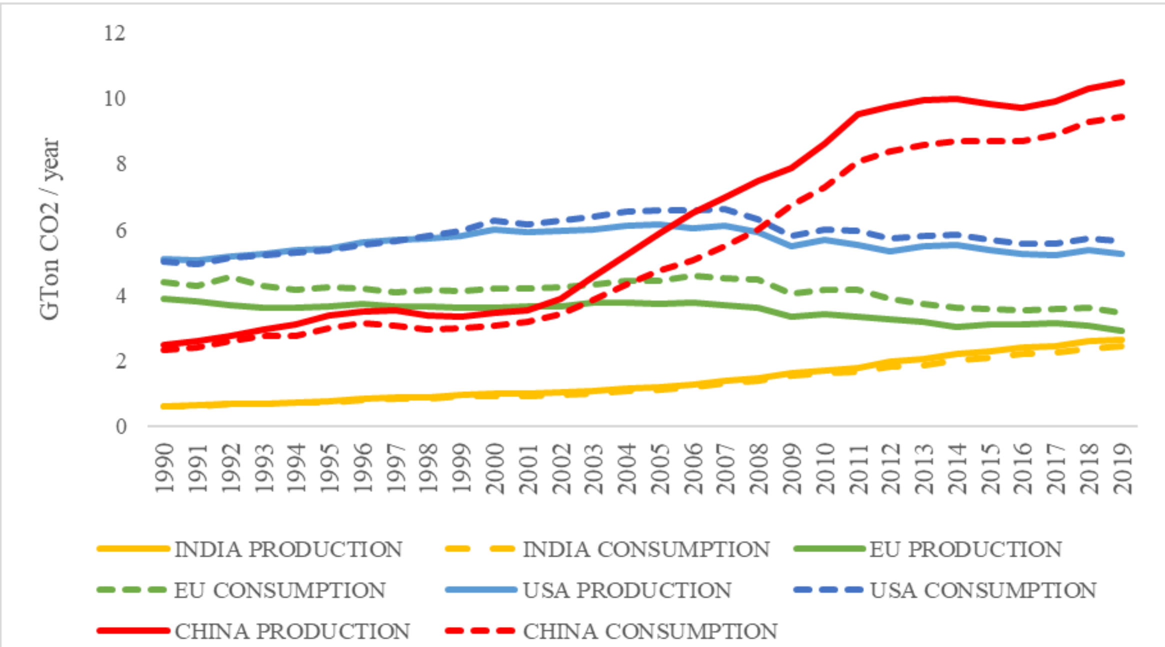
Source: IPCC (2022)

[6] List of countries and regions included in the annex II IPCC, 2021, available at https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_Annex-II.pdf

Another perspective to examine CO_2 emissions is relative to consumption, as illustrated in Figures 2-3 and 2-4. This metric is calculated by modifying the conventional production-territorial-based emissions to incorporate the impact of global trade. This method involves adding emissions embodied in imports and subtracting emissions embodied in exports. Consequently, consumption-based emissions attribute emissions to the places where goods and services are consumed. Looking at the distribution of fossil CO_2 emissions based on consumption offers an alternative viewpoint. In this case, the conclusion is that the USA and the EU27 are net importers of embodied emissions, and China and India are net exporters. In countries such as France, Germany, Italy, and Spain, over 40% of national CO_2 footprints are attributed to imports. This highlights the importance of addressing global issues while also maintaining a local perspective to prevent the exporting of industries, labour, and emissions overseas. Additionally, it is crucial to identify the proper responsibilities in this context.

Figure 2-3

CO_2 emissions: Territorial production and consumption 1990-2019

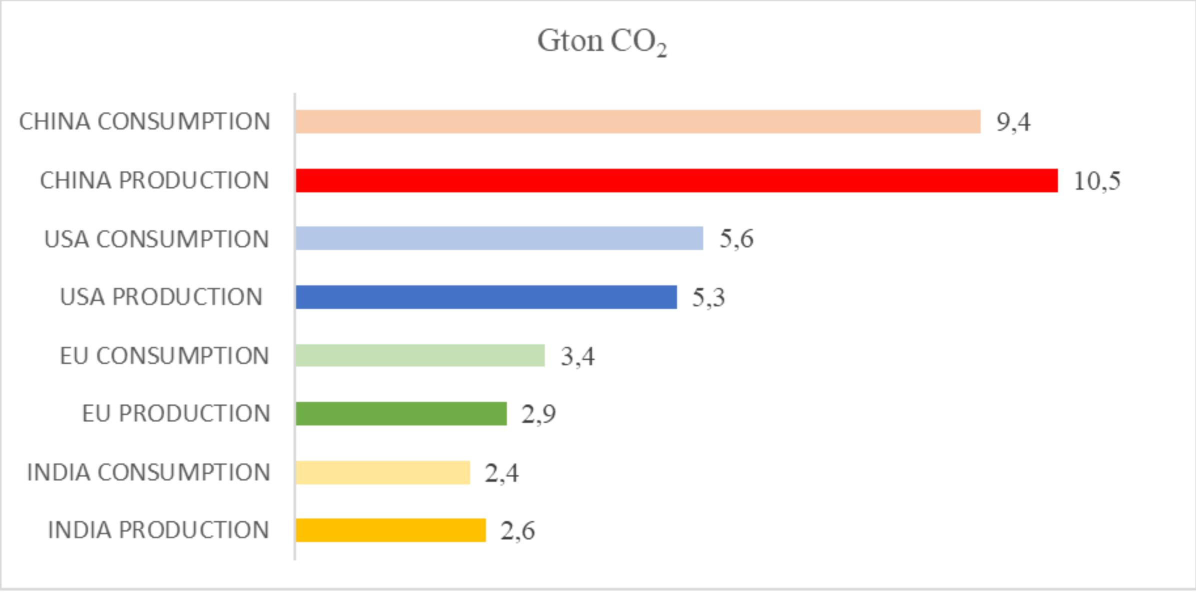


Source: Global Carbon Budget (2022). Data downloaded October 2022[7]

[7] Database available at https://www.globalcarbonproject.org/carbonbudget/22/data.htm

Figure 2-4

CO_2 emissions: Territorial production and consumption in 2019



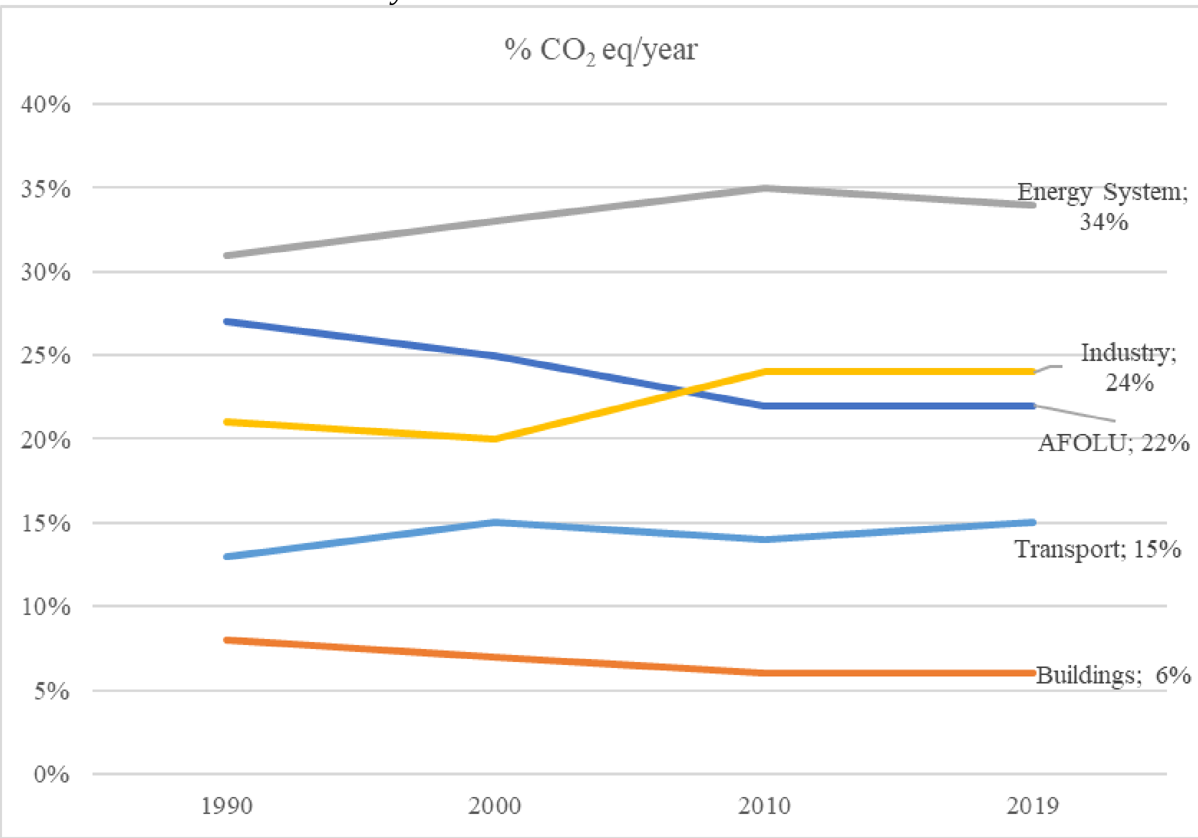
Source: Global Carbon Budget (2022). Data downloaded October 2022

b) Sectors and GHG emissions:

The IPCC, 2022 report also examines GHG emissions by sector. Over the last 30 years, the single largest contributor to global GHG emissions is the energy system. The latest figure published by IPCC for world GHG emissions is 59 $GtCO_2$-eq in 2019 and, as illustrated in Figure 2-5, the energy system produced 20 $GtCO_2$-eq, which represents 34% of total emissions. Most of this is derived from electricity and heat generation (69%) with 14 $GtCO_2$-eq, with the remainder coming from fugitive emissions (oil, gas, and coal with 19%), petroleum refining 3%, and other energy systems with 8%.

The other sectors contributing to the global GHG emissions in 2019 are industry (24%), agriculture, forestry, and other land use (AFOLU, with 22%, and transport and buildings with 15% and 6%, respectively.

Figure 2-5
World GHG emissions share by sector



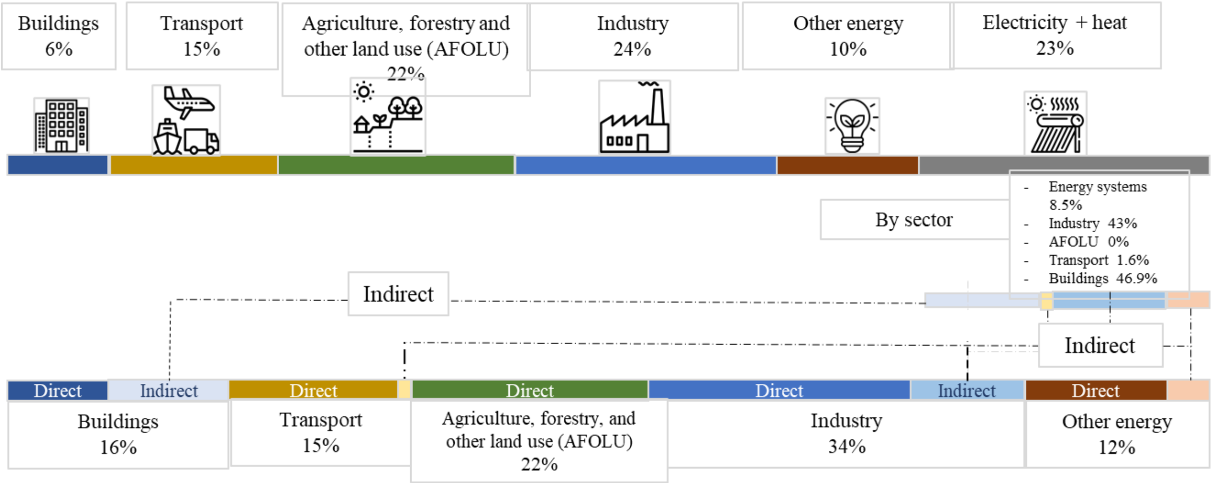
Source: IPCC (2022)

A further angle considered in the analysis of global GHG emissions from the energy system is achieved by looking at the use of energy, as we did with the world region-level emissions, based on consumption. In this case, IPCC, 2022 reallocates energy produced from electricity and heat generation to the end-use by the industry and buildings sectors. The following changes shown in Figure 2-6 can be noted in 2019:

- The industry sector increases from 24% to 34% (metals, chemicals, waste and cement processing)
- The buildings sector increases from 6% to 16% (residential and non-residential)

Figure 2-6

Direct and indirect GHG emissions by sectors in 2019

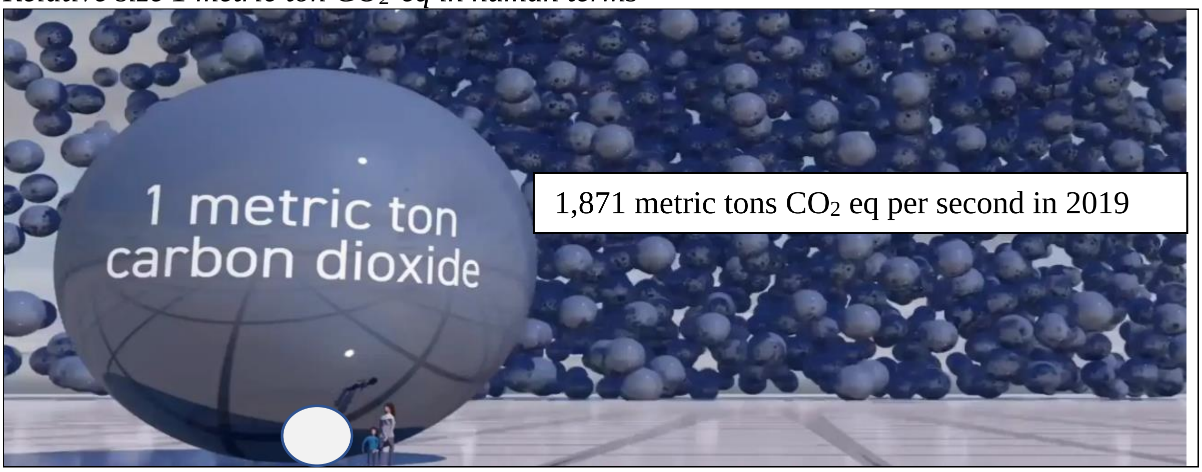


Source: IPCC (2022)

In general terms, human behaviour is inadequate at responding to invisible threats. We react quickly if something visible threatens us, but anything intangible tends to be ignored, as is the case with GHG. To put it into perspective, the 59 Giga tons of CO_2-eq global emissions produced in 2019 are equivalent to 1,871 metric tons produced per second and the scale of 1 metric ton in human terms can be shown as follows:[8]

Figure 2-7

Relative size 1 metric ton CO_2-eq in human terms



Source: Real world visuals[9]

[8] Note: 59 Giga tons CO_2-eq per year =59 x 10^9 metric tons / 31,536,000 seconds= 1,871 metric tons per second.

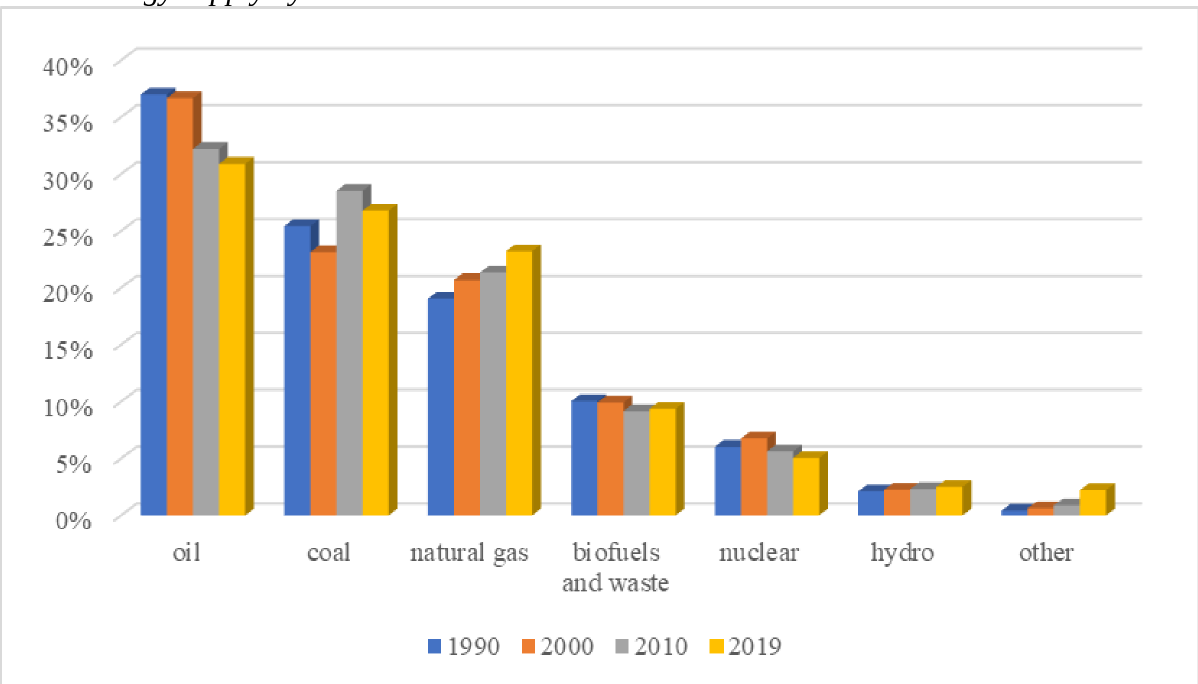
[9] Real world visuals available at https://www.realworldvisuals.com/

This is the point when we must focus our lens to examine the degree to which human activities related to the source of energy are generating GHG emissions to determine the necessary course of action. By analysing worldwide sources of energy during the last 30 years, we can identify that fossil fuels, represented by oil, coal, and natural gas are the main sources of energy.

At the same time, over the last 30 years, the first three dominant energy sources in terms of GHG emissions have been coal, oil, and then natural gas.

According to the latest global data from the IEA in 2019 (IEA, 2021a), Figure 2-8 displays that oil accounted for 30.9%, coal for 26.8%, and natural gas for 23.2% of the overall energy supply. Nuclear energy made up 5%, and renewable energy sources - such as biofuels, renewable municipal waste, hydro, solar PV, solar thermal, wind, geothermal, and tidal energy - contributed 14.1%. The progressive increase in renewable energy sources is remarkable from 12.5% in 1990 to 14.1% in 2019.

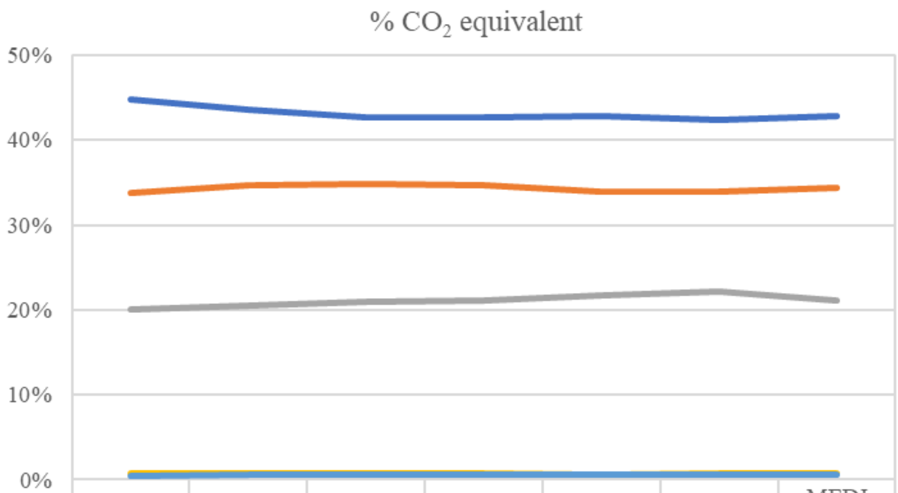
Figure 2-8
World energy supply by source 1990-2019



Source: IEA (2021a)

The share of GHG emissions derived from energy is illustrated in Figure 2-9. The median energy-related global GHG emissions between 2014 and 2019 show that coal contributes approximately 43% of CO_2 eq. emissions, while oil and natural gas account for 34% and 21%, respectively. The remaining portion comprises biofuels, waste, and other energy sources, according to the International Energy Agency (IEA, 2021b).

Figure 2-9
Fuel share of GHG emissions from energy



	2014	2015	2016	2017	2018	2019	MEDIAN
coal, peat and oil shale	44,8%	43,5%	42,7%	42,7%	42,9%	42,4%	42,8%
oil	33,8%	34,7%	34,9%	34,7%	34,0%	33,9%	34,3%
natural gas	20,1%	20,5%	21,0%	21,2%	21,7%	22,2%	21,1%
biofuels and wastes	0,8%	0,8%	0,8%	0,8%	0,8%	0,8%	0,8%
other	0,5%	0,5%	0,6%	0,6%	0,6%	0,6%	0,6%

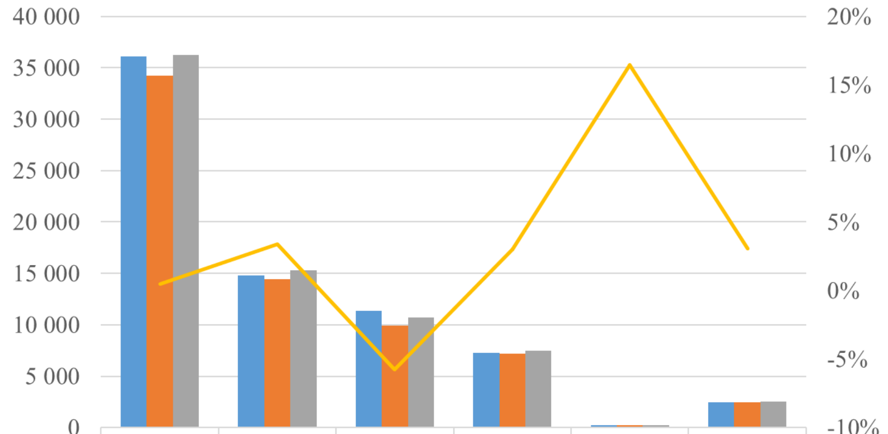
Source: IEA (2021b)

The most recent figures after 2019 are influenced by the Covid-19 pandemic and its impact on energy demand in 2020 and the rebound of activity after lockdowns in 2021.

During 2020 global CO_2 emissions from energy combustion and industrial processes decreased by 5.1%, while the recovery in 2021 produced a 6% increase in CO_2 emissions, in line with the increase in global GDP of 5.9%, according to IEA (2022). This means that emissions increased above the pre-pandemic levels during 2021, as shown in Figure 2-10.

The main growth drivers from 2019 to 2021 come from the growth combustion of coal (3.39%), gas (3.01%), and biomass and waste (16.45%), partially compensated by the oil decrease (-5.74%) as the pandemic continued to impact oil use for transport in 2021. The remaining driver comes from industrial processes, which increased their emissions by 3.08%.

Figure 2-10
CO_2 emissions from energy combustion and industrial processes



	Total CO2 emissions	Coal	Oil	Gas	Biomass and waste	Industrial process
Energy and process CO2 emissions (Mt CO2) 2019	36 077	14 768	11 344	7 270	231	2 464
Energy and process CO2 emissions (Mt CO2) 2020	34 221	14 409	9 940	7 164	242	2 465
Energy and process CO2 emissions (Mt CO2) 2021	36 257	15 268	10 693	7 489	269	2 540
Growth Rate (%) 2019-21	0,50%	3,39%	-5,74%	3,01%	16,45%	3,08%

Source: IEA (2022)

Based on the detailed information provided above, we can conclude the following:

- Emissions measured on a consumption basis reflect the fact that the USA and the EU27 are net importers of embodied emissions, and China and India are net exporters. In countries such as France, Germany, Italy, and Spain, over 40% of national CO_2 footprints are attributed to imports.
- Over the last 30 years, the single largest contributor to global GHG emissions has been the energy system (approximately one-third of global emissions).
- The worldwide energy mix is fundamentally based on fossil fuels (oil, coal and gas), despite the remarkable increase in renewable energy sources from 12.5% in 1990 to 14.1% in 2019 over the total energy supply.

- The combustion of fossil fuels and industrial processes are the main emissions drivers.
- The coal and oil and gas sectors are the largest contributors, both directly in terms of the supply of energy and indirectly in terms of their users´ sectors (industry, transport, and buildings).

These interactions are particularly relevant because any change in either the source or the use of energy has interdependencies with significant impacts between the sectors. The following figure illustrates the significant transformation required to change the current fossil fuel energy mix to lower carbon fuels:

Figure 2-11
The relative size of each energy supply

Source: IEA (2021a)

For these reasons, we can affirm that to achieve the aim to limit GHG emissions, our society needs to undergo a significant transformation.

Within this context, it is our view that climate change and its effects have reached a very relevant place among society's priorities. Most companies, financial institutions, governments, and policymakers are pursuing initiatives to address the energy transition to a model of lower GHG emissions to mitigate the risks associated with climate change.

2.2 Climate change and the institutional agenda

As will be explained in more detail in the following section, this awareness process has gained incremental attention in recent years. The basis for the present was founded back in 1979, when the first World Climate conference took place in Geneva, organised by the World

Meteorological Organization, focusing on global climate issues. The United Nations has been at the forefront of the effort to shed light on the global challenge of climate change and human development. Table 2-1 presents the key milestones in their institutional agenda.

Table 2-1

Most relevant milestones in the United Nations´ agenda

1979	The first World Climate Conference took place
1987	The World Commission on Environment and Development published "Our Common Future"
1988	Set up the Intergovernmental Panel on Climate Change (IPCC)
1992	UNFCCC: The United Nations Framework Convention on Climate Change at the Rio Eath Summit
1997	COP3 – KYOTO Kyoto Protocol: Emissions reduction
2007	COP13 – BALI Bali Road Map
2009	COP15 – COPENHAGEN Copenhagen Agreement: Long-term financing. 2ºC challenge
2010	COP16 – CANCUN Cancun Agreements
2011	COP17 – DURBAN Durban Platform
2012	COP18 – DOHA Doha Amendment: 21st Stage of the Kyoto Protocol
2013	COP19 – WARSAW International Warsaw Mechanism
2015	COP21 – PARIS: Paris Agreement
2016	COP22 – MARRAKESH Marrakesh Partnership: The Paris Agreement comes into effect
2017	COP23 – FIJI Held in Bonn
2019	COP25 – CHILE Held in Madrid
2021	COP26 – GLASGOW

Note: Green colour denotes agreements of a higher level of influence and commitment

The "Brundtland Report," also known as "Our Common Future," presented to the General Assembly in 1987 by the World Commission on Environment and Development, marked the first significant effort towards sustainable development. This report, which was the result of a four-year study, outlined that sustainable development must satisfy the current generation's requirements while also ensuring that future generations can fulfill their own needs without any hindrance.

The United Nations Framework Convention on Climate Change (UNFCC) was produced during the 1992 "Earth Summit," marking the initial step towards addressing the issue of climate change. The Convention now boasts near-universal membership, with the 197 nations that have ratified it referred to as the Parties of the Convention.

By 1995, countries had initiated discussions to enhance the global response to climate change, leading to the adoption of the legally binding Kyoto Protocol two years later. The Protocol mandates emission reduction targets for developed country Parties, with the first commitment period lasting from 2008 to 2012 and the second commitment period from 2013 to 2020. Currently, there are 192 Parties to the Kyoto Protocol.

The United Nations promoted the Sustainable Development Goals (2015-2030), an initiative that outlined 17 goals and 169 targets, encompassing novel areas such as climate change, economic inequality, innovation, sustainable consumption, peace, and justice. On 25 September 2015, a summit was held in New York, where the goals and targets were adopted; they entered into force on 1 January 2016.

The Paris Agreement, established in 2015, provided a definitive path for the future decades. Its objective is to reinforce the worldwide reaction to the menace of climate change within the context of sustainable development and the endeavour to eliminate poverty. The objectives include limiting the increase in the global average temperature to well below 2 °C above pre-industrial levels, with the stated ambition being to limit the temperature increase to 1.5 °C above pre-industrial levels, acknowledging that doing so would significantly reduce the risks and impacts of climate change. Additional goals encompass a periodic reassessment of nations' commitment to curtailing emissions every five years and the provision of climate funding to developing countries. Achieving the objectives of the 2015 Paris agreement will require a significant reduction in carbon emissions.

Since the 2015 agreement was reached at the COP 21 an inflection point occurred. The level of renewed commitment was gauged again in 2021 at COP 26 in Glasgow with the adoption of the Climate Pact. The aim was to pursue efforts to limit the temperature increase to 1.5º C and provide the necessary finance for climate adaptation, including compensation for loss and damage. Within the package of decisions, the Parties finalized the Paris Agreement's rulebook, which governs the transparent reporting of climate actions and market mechanisms. The market mechanisms encourage the transfer of emission reductions between nations and incentivise private sector investments in climate-friendly solutions. Non-market approaches were also adopted to strengthen the cooperation between countries concerning mitigation and adaptation.

2.3 Climate-related risks

In the context of the scenario described above, it is necessary to identify the risks associated with climate change to frame the relationship between financial markets, the energy sector, and the oil and gas companies, which is the focus of our research.

The term risk in this context may be defined as the probability of something that deviates from average behaviour happening. Although there exists an international risk management standard (IEC 31010, which defines risk as the "effect of uncertainty on objectives"), determining concrete risks can still be challenging when dealing with particular areas of knowledge and sectors.

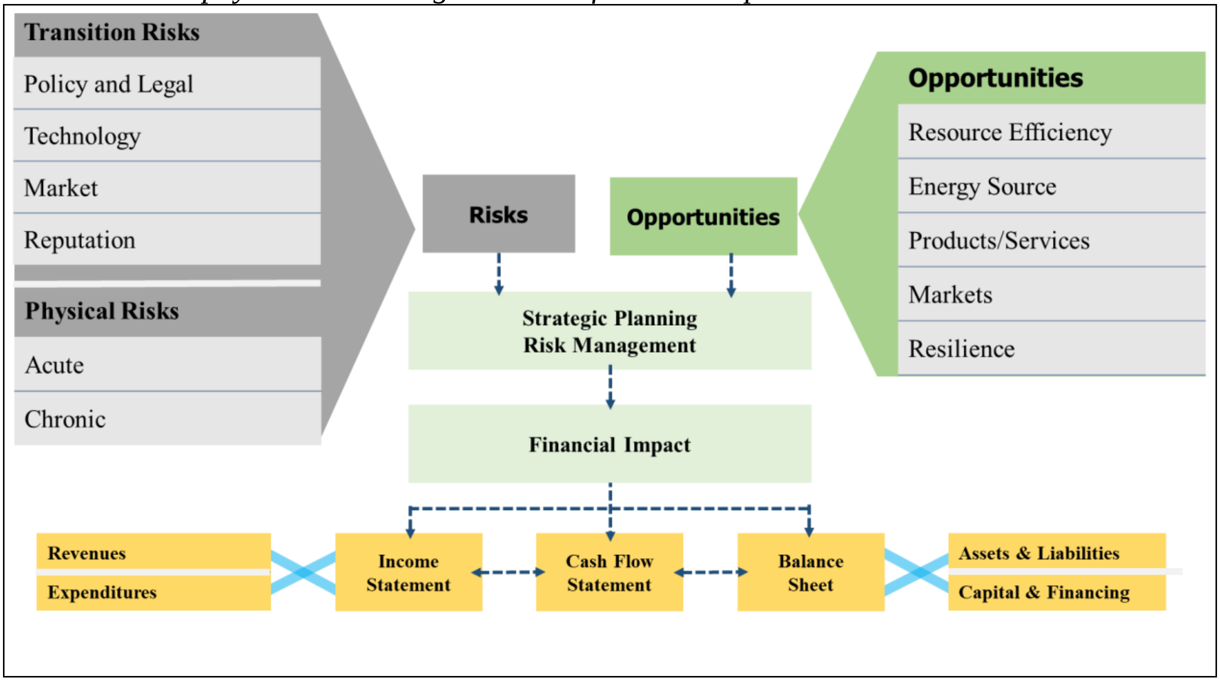
As the most recognized scientific authority on climate change, the IPCC has been advocating for a uniform and transparent utilization of the concept of risk. The authors and Technical Support Units of the Working Groups of the sixth assessment cycle released a revised definition of risk in September 2020. In the context of climate change, risks can emerge from the possible impacts of climate change and/or reactions to climate change, which may include the absence of any response to the problem.

In line with the IPCC (2020) report, a significant disparity is that in finance and investment, the term "risk" does not exclusively pertain to adverse outcomes. Instead, it describes the possibility of actual consequences differing from their anticipated value, which may be favourable or unfavourable. Furthermore, some literature employs the term "risk" solely in situations where potential consequences can be measured in advance, rather than when they rely on qualitative assessments or profound uncertainties.

Despite the variations in the usage of the term "risk," there is ample consensus in both the academic literature and the practitioner community regarding the categorization of climate-related risks into "physical risk" and "transition risk". "Physical risk" primarily concerns the hazards and risks arising from climate change impacts and climate-related dangers, while "transition risk" typically pertains to the hazards linked with transitioning to a low-carbon economy.

The Task Force on Climate-related Financial Disclosures (TCFD) is one of the primary resources for reference in this field. The TCFD was established by the Financial Stability Board, a global organization that endeavours to reinforce and safeguard worldwide financial markets from systemic risks such as climate change. As described in Figure 2-12, TCFD's recommendations are designed to enhance the disclosure of climate-related financial data, risks, and opportunities, enabling them to be integrated into business and investment decision-making processes.

Figure 2-12
Transition and physical risks integration and financial impact



Source: TCFD (2017)

In summary, based on IPCC and TCFD, physical risks are those that arise from the hazard, exposure, and vulnerability framework. This includes risks to facilities and infrastructure, operations, water and raw material availability, and disruptions in the supply chain. These risks can have direct financial consequences for organizations and may require upfront costs for insurance and investment. Physical risks can be divided into two types: (i) acute risks, which are event-driven and include extreme weather events like floods, hurricanes and cyclones, and (ii) chronic risks which refer to longer-term changes in climate patterns such as sustained higher temperatures that could lead to chronic heat waves or sea level rise.

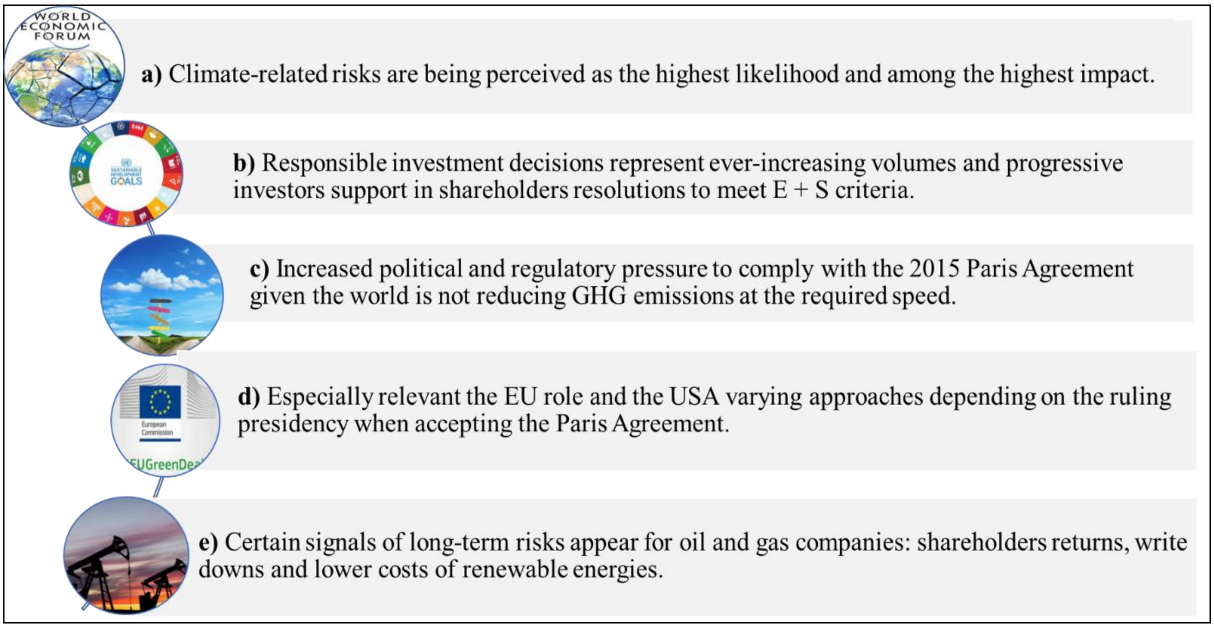
On the other hand, transition risk refers to risks associated with the transition to a low-carbon economy or a carbon transition risk. This includes risks related to policy and legal changes, technology, market changes, and reputation, among others, to address mitigation and adaptation. Transition risks may affect companies' financial performance, especially those that rely on fossil fuels or have high carbon intensity. The degree of financial and reputational risk to organizations caused by transition risks may vary depending on the nature, speed, and focus of these changes. As a result, organizations may face stranded assets, market loss, reduced return on investments, and financial penalties.

Various subcategories of risks associated with climate change have been identified through a literature review as outlined by Venturini (2022). These risks encompass a broad range of areas, including policy, legal, litigation, technology, market, liability, solvency, and reputational risks. The severity of these risks may vary, as they can emerge from either physical or transition risks.

2.4 Accelerating signals affecting the energy sector and oil and gas companies

We aim to illustrate the significance of the research by highlighting certain indicators that point to the growing recognition of climate-related risks (see Figure 2-13). We believe that society is becoming increasingly aware of transition risk, and we have identified several factors and signals that may be accelerating this trend and already impacting the energy sector, especially oil and gas companies.

Figure 2-13
Transition risk awareness: Accelerating factors and signals



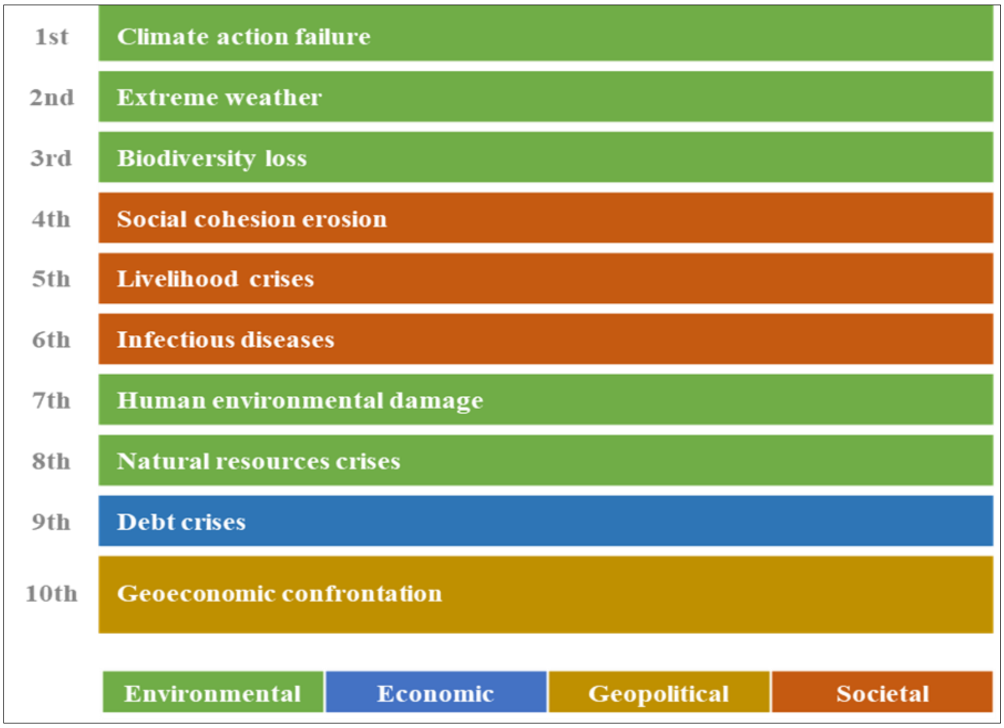
***a) Higher perception of climate-related risks*.**

According to the World Economic Forum (2022) survey, climate-related risks are perceived as those having the highest likelihood and the highest impact.

The Global Risk Survey report, published in 2022, identified “climate action failure” as the leading long-term threat and the risk having potentially the most severe impacts over the next decade. As illustrated in Figure 2-14, the two most severe risks identified are “climate action failure” and “extreme weather”.

Figure 2-14

Top 10 most severe risks on a global scale over the next decade



Source: World Economic Forum (2022)

Climate change continues to be perceived as the most serious threat to humanity, with the survey results being in the top five positions since 2014. The reports from 2020 and 2021 highlighted that extreme weather, climate action failure, human-led environmental damage, and natural disasters are among the most probable risks that will arise in the coming decade. Infectious diseases were identified as the topmost concern among the risks with the highest impact in 2021, followed by climate action failure and other environmental risks. When compared with 2020, the highest impact risk was climate action failure.

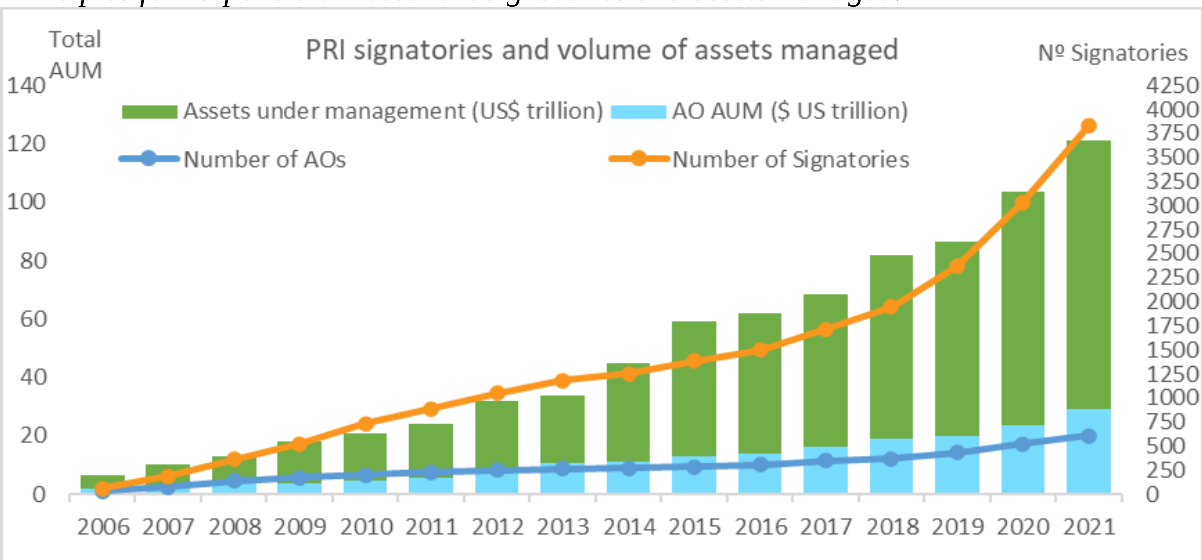
b) Responsible investment decisions.

Every year the number of institutional investors adhering to the United Nations Principles for Responsible Investment (PRI) is rising.

Although the PRI was developed in 2005 through the joint initiative of the United Nations and a reduced group of international institutional investors, its relevance has been growing more recently. Responsible investment is defined by the PRI as both a practice and a strategy that involves the integration of environmental, social, and governance (ESG) factors into investment decisions and active ownership. The PRI identifies three key entities involved in responsible investment: a) asset owners, who hold long-term retirement savings, insurance policies, and similar assets, including pension funds, sovereign wealth funds, foundations, endowments, insurance and reinsurance companies, as well as other financial institutions managing deposits; b) investment managers, who act as third-party controllers of investment funds, serving both institutional and retail markets; and c) service providers who offer services or products to asset owners and/or investment managers.

As shown in Figure 2-15, the significance of the PRI has increased by more than two-fold since 2015; in that year, the assets under management (AUM) represented USD 59 trillion and the asset owners (AO UM) accounted for USD 13.2 trillion, with a total of 1,384 signatories, while in April 2021 the AUM and the AO UM represented USD 121.3 trillion and USD 29.2 trillion, respectively, with a total of 3,826 signatories.

Figure 2-15
Principles for responsible investment signatories and assets managed.

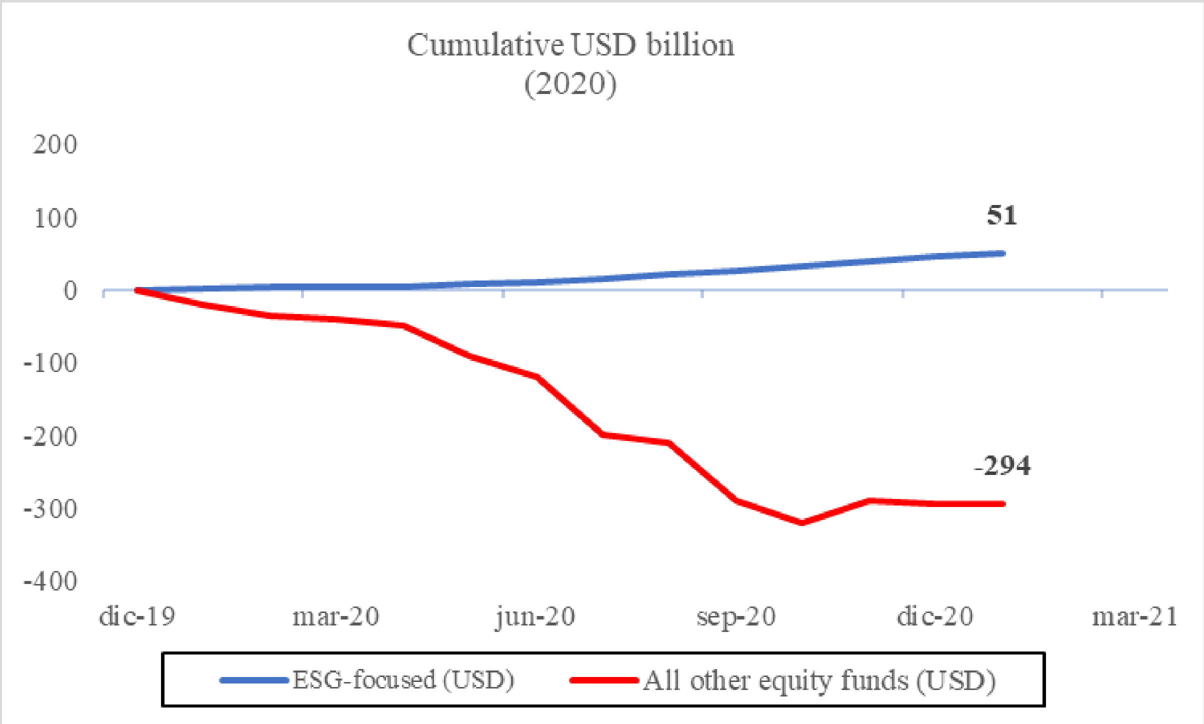


Source: Principles for Responsible Investment. Data downloaded as of April 2021[10]

[10] Database available at https://www.unpri.org/about-us/about-the-pri

Firstly, this can drive us to analyse how the investment is directed with ESG criteria, whereby, as reflected in Figure 2-16, we can identify a growing volume of equity flows over the last few years. According to Goldman Sachs (2021), US ESG-focused equity fund inflows in 2020 totalled USD 51 billion, two times larger than the cumulative inflows of USD 25 billion between 2015 and 2019, while all other equity funds in 2020 decreased by USD 294 billion.

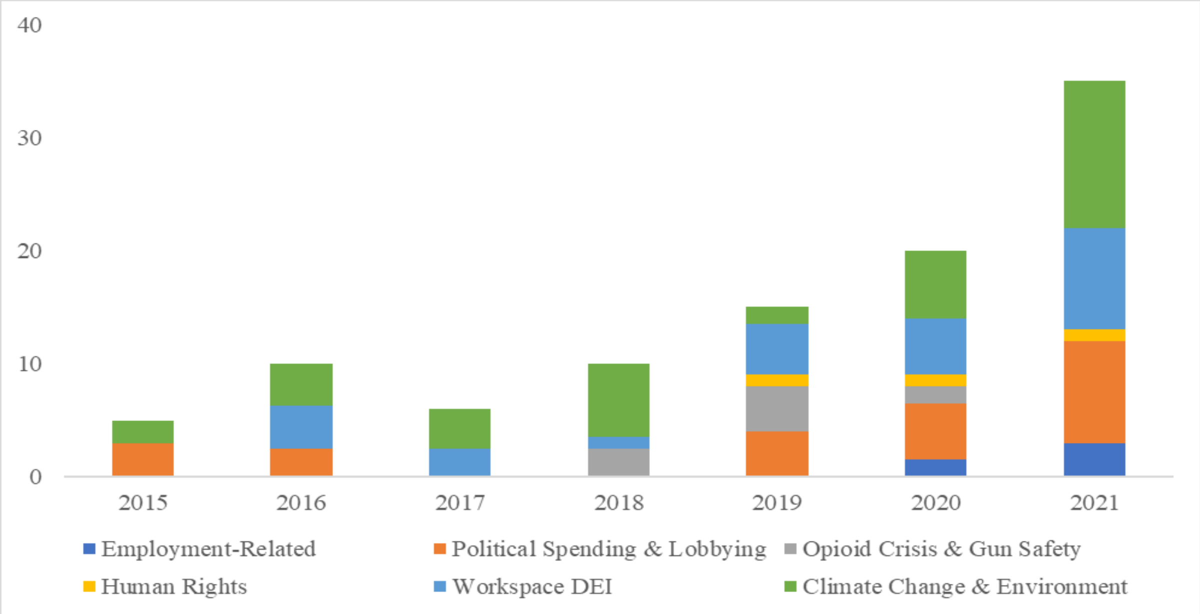
Figure 2-16
US equity flows to ESG-focused funds comparison.



Source: Goldman Sachs (2021)

Secondly, as illustrated in Figure 2-17, there is a growing trend of investors showing support for environmental and social (E&S) shareholder resolutions, which has reached a new record in the proxy season as of July 2021. In particular, resolutions supported by investors related to climate change and the environment have witnessed a remarkable surge since 2015 and are currently in a dominant position. A corporate proxy ballot represents a barometer for changing corporate behaviour, whereby shareholders propose resolutions. Their votes are not binding but acquire relevance when supported by a majority of shareholders.

Figure 2-17
The majority supported environmental and social resolutions



Source: Morning Star. Note: Data as of July 2021[11]

c) Increased political and regulatory pressure to comply with the 2015 Paris Agreement.

The magnitude of the challenge involved in achieving the aims of the Paris Agreement is paramount, and the decoupling between carbon emissions and economic growth is necessary, as we need to achieve global warming-related goals. An estimate by United Nations Conference on Trade and Development (UNCTAD, 2020) indicated that global GHG emissions declined by 8%, or 2.6 Gigatons, in 2020 when COVID-19 forced most countries to shut down and hibernate their economies.

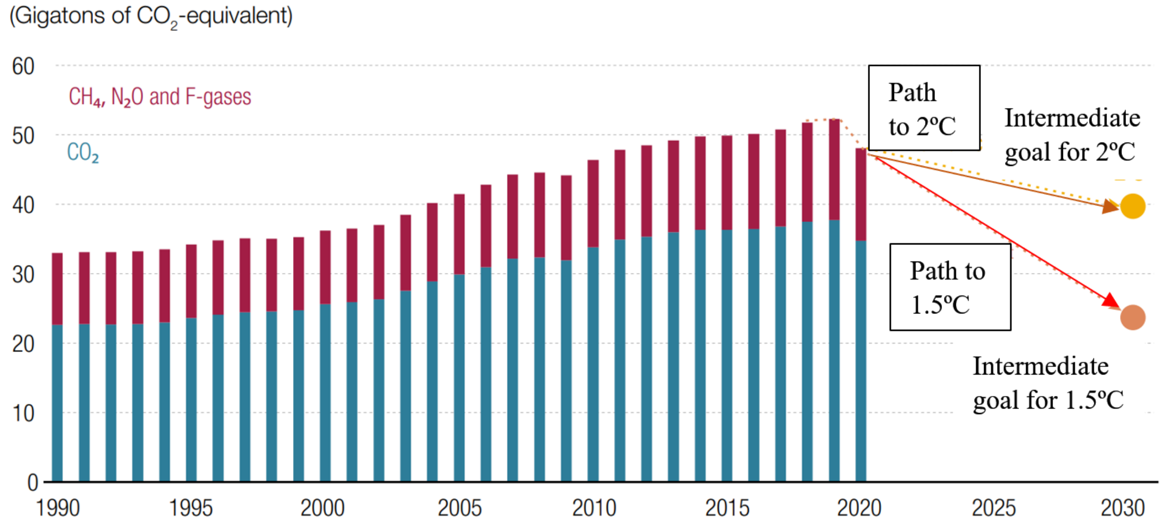
To put this in context, Figure 2-18 shows how a similar decrease of 8% would be needed every year for the next decade to reach the intermediate goal of limiting global warming to 1.5°C by 2030, without sacrificing economic growth. However, similarities to the 2008-2009 financial crisis are shown, when economic recovery led to a rebound in emissions. This could

[11] Data available at https://www.morningstar.com/articles/1052234/the-2021-proxy-voting-season-in-7-charts

happen again unless policy and regulatory stimulus create the conditions needed to accelerate the transition to a lower-carbon economy.

Figure 2-18

GHG emissions and Paris Agreement alignment.



Source: UNCTAD calculations, based on Netherlands PBL (2019) and United Nations Environment Programme (2019).
Abbreviations: CH_4, methane; CO_2, carbon dioxide; N_2O, nitrous oxide; F-gases, fluorinated gases.

Source: UNCTAD (2020)

With these figures in mind, it is crucial to investigate further to predict the level of CO_2 emissions that the atmosphere can absorb by restricting the temperature increase to 1.5ºC. According to the IPCC Working Group I (2021), the remaining "carbon budget" can be estimated based on the probability of achieving this target. If there is a 50% likelihood of limiting global warming to 1.5ºC, then the world could emit 500 Gt CO_2 from the start of 2020. This is equivalent to approximately 9 years of global CO_2 emissions if they remain at current rates and do not start declining. On the other hand, if emissions decline, the carbon budget would last longer.

Considering only CO_2 emissions (not all GHG emissions) to achieve net zero by 2050, an annual reduction of approximately 1.4 Gt CO_2 would be necessary, which is almost equivalent to the decline observed in 2020 due to the COVID pandemic (Global Carbon Project, 2022). The biggest challenge is that, although we are aware of the volume of emissions we must cut to reach these objectives, the world is still not reducing them at the required speed.

d) The role of the European Union and the USA in the fight against climate change.

The European Union (EU) has been playing a substantial role. To signify some recent developments, in 2014 the European Council[1] approved “the 2030 package”, setting ambitious GHG emission reduction targets; this was followed in 2019 by the “European Green Deal” which set out the vision to become the first climate-neutral continent and a plan for how to achieve EU neutrality by 2050.

More recently, it is particularly relevant that in response to the COVID-19 pandemic, the EU has implemented a recovery package that aims to boost investment in both the green and digital transitions. As part of this recovery package and the 2021-2027 budget, the European Union Council agreed in July 2020 that 30% of the funds, amounting to €1.8 trillion, should be dedicated to accelerating the climate transition.

The European Commission (2020) has identified several areas that have the greatest potential for stimulating the economy through climate and energy policy. These areas include renewable energy, renewable hydrogen, infrastructure development, building renovation, and clean mobility options like electric vehicles and charging points, smart grids, and energy sector integration.

On the other hand, the United States has taken different approaches to address climate change, with varying degrees of commitment[12]. The country's adherence to the Paris Agreement has been uncertain, depending on the ruling presidency. During President Obama's term, the United States entered into the Agreement without submitting it to the Senate for advice and consent, and it became a Party when the Agreement entered into force in 2016. However, President Trump announced the country's withdrawal from the Agreement in June 2017, and it

[12] See (CRS) Congressional Research Service. (2021, October 28). *U.S. Climate Change Policy*. https://crsreports.congress.gov/product/pdf/R/R46947. CRS serves as shared staff to congressional committees and Members of the USA Congress.

became effective in November 2020. More recently, President Biden once again accepted the Agreement, and the United States resumed its status as a Party on February 19, 2021.

e) The appearance of long-term risks.

As the transition to a lower-carbon economy changes consumer preferences, reduces long-term demand for oil and gas, and inspires new technological developments, some additional long-term risks are emerging for companies in the oil and gas sector, such as access to capital and insurance, portfolio divestments and, as described before, reputational matters, increased regulatory pressure and stakeholders´ activism.

The following indicators can help identify the potential impacts of transition risks on financial performance; these are discussed as follows.

i) *Total shareholder's return* can be reflective of the incorporation of some of these risks in oil and gas companies when we compare them with clean energy companies. Such is the case when we compare the total return of the S&P Global 1200 Energy Sector Index (Energy Index) [13], whose constituents are mainly oil and gas companies, with clean energy companies included in the S&P Global Clean Energy Index (Clean Index).

As Table 2-2 and Figure 2-19 show, over the last decade (October 2012-December 2021), the Clean Index has performed significantly better than the Energy Index, generating a total return that is more than three times greater. Specifically, the Clean Index's total return increased by 376%, while the Energy Index's total return only increased by 104%. More recently, when compared until October 2022, the returns are 318% and 141%, respectively.

If we analyse a closer period, since the last crude oil price crunch in 2014, from January 2014 to December 2020, the result is that the Energy Index dropped by 35%, and the Clean Index increased by 207%. These differences are reduced when compared with December 2021,

[13] The S&P Global 1200 Energy Index consists of all members of the S&P Global 1200 that are classified within the GICS® energy sector (Global Industry Classification Standard).

with an 8% drop and 136% increase respectively. In any case, we can realise the relative outperformance of the Clean Energy Index.

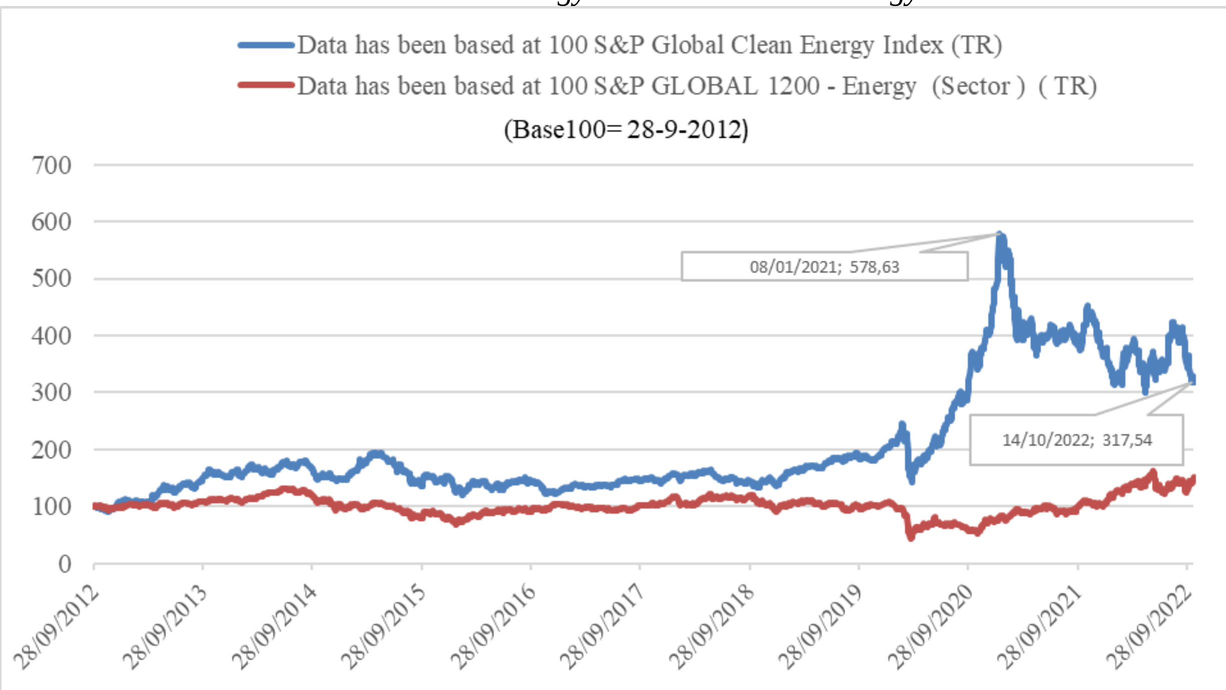
Table 2-2

Total return growth S&P Global Clean Energy Index vs Global Energy Index (2014-2021)

	 S&P Global Clean Energy Index (TR)	 S&P Global 1200 Energy Sector (TR)
28/09/2012	100	100
02/01/2014	159,6	113,39
31/12/2020	490,08	73,91
31/12/2021	376,46	104,83
14/10/2022	317,54	141,03
% Growth (2014-2020)	207%	-35%
% Growth (2014-2021)	136%	-8%

Figure 2-19

Total return series S&P Global Clean Energy Index and Global Energy Index



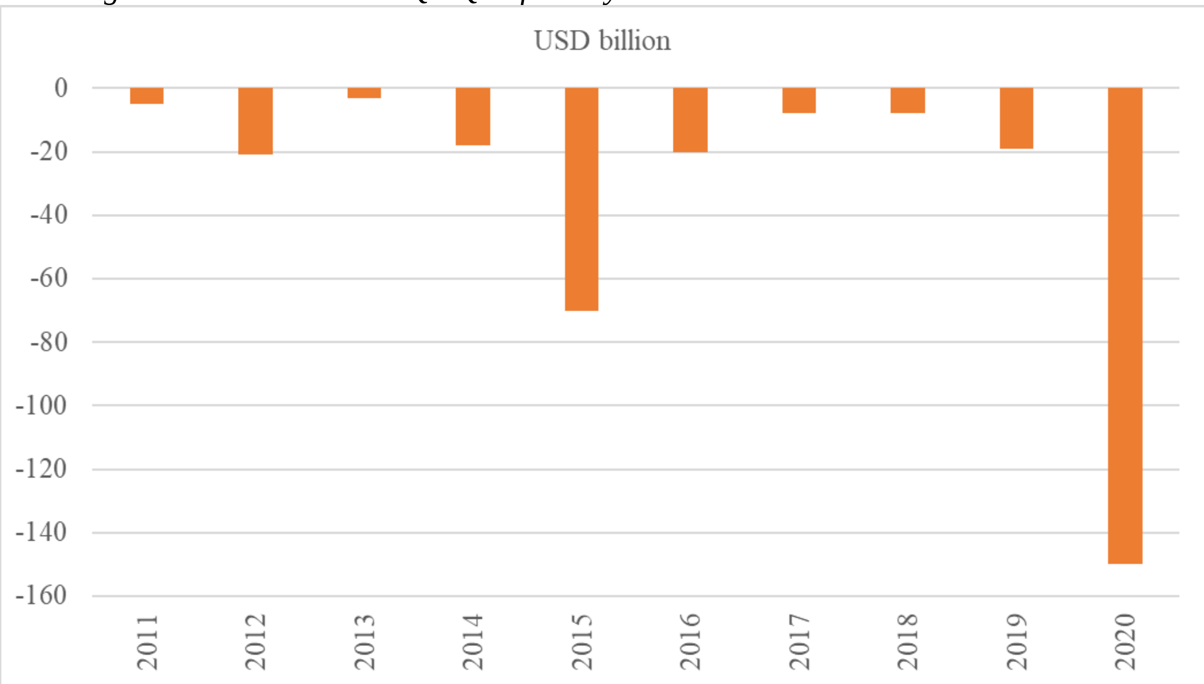
Source: S&P Dow Jones Index

ii) The book value of oil and gas companies in 2020 recorded significant write-downs on carbon-intensive assets as a result of their commitments and targets to reach net zero emissions by 2050.

According to Eaton and McFarlane (2020), the impairments faced by oil companies in 2020 were some of the most severe ever experienced. In addition to the impacts of the coronavirus pandemic, companies also faced uncertainty over future prices and demand for their main products. Figure 2-20 shows that during the first three quarters of 2020, oil and gas companies in Europe and North America wrote down approximately $145 billion, the highest amount for that period since at least 2010. This represents about 10% of the companies' market value.

These asset write-downs have represented a significant negative impact on net income and shareholders' equity and recognition of the future deterioration of operating cash flow generation in the financial statements of most relevant oil and gas companies.

Figure 2-20
Oil and gas assets write-downs Q1-Q3 of each year 2011-2020

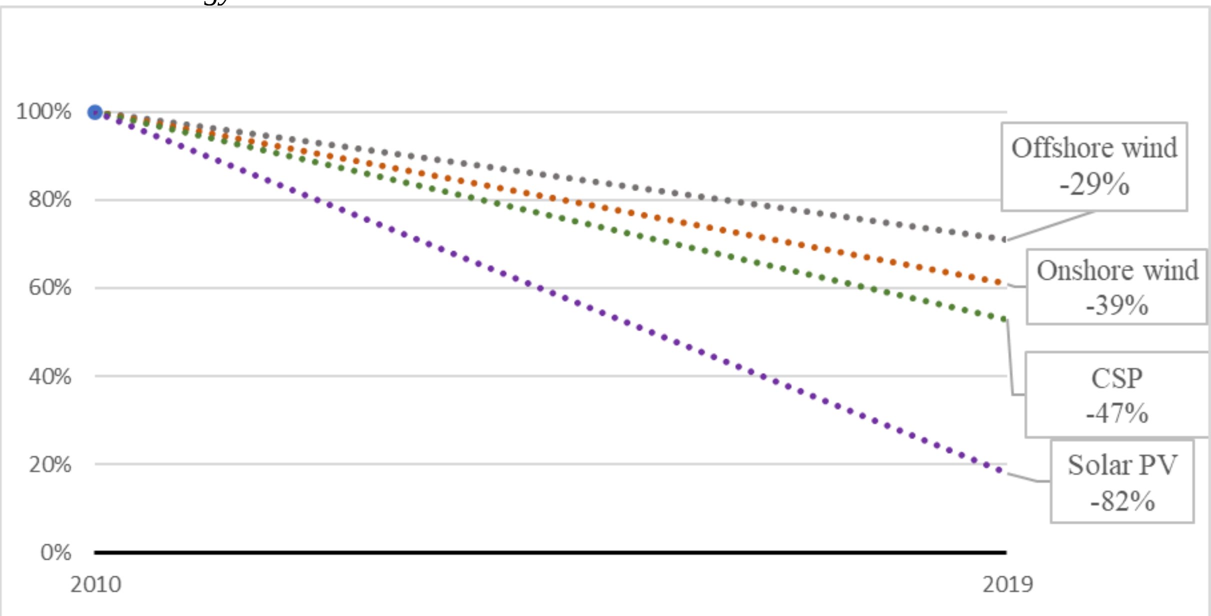


Source: Eaton and McFarlane (2020)

iii) Lower costs in renewable energy technologies are facilitating the speed of change to lower carbon-intensive energy models.

Renewable electricity costs have significantly decreased over the last ten years, as stated by the International Renewable Energy Agency (IRENA, 2020a). This drop can be attributed to better technology, economies of scale, more competitive supply chains, and increasing developer expertise. In particular, as described in Figure 2-21, solar photovoltaic (PV) costs dropped by 82% since 2010, followed by concentrated solar power (CSP) at 47%, onshore wind at 39%, and offshore wind at 29%. Moreover, the costs of 56% of all newly commissioned utility-scale renewable power generation capacity in 2019 were less expensive than the cheapest fossil fuel-fired option.

Figure 2-21
Renewable energy cost reductions.

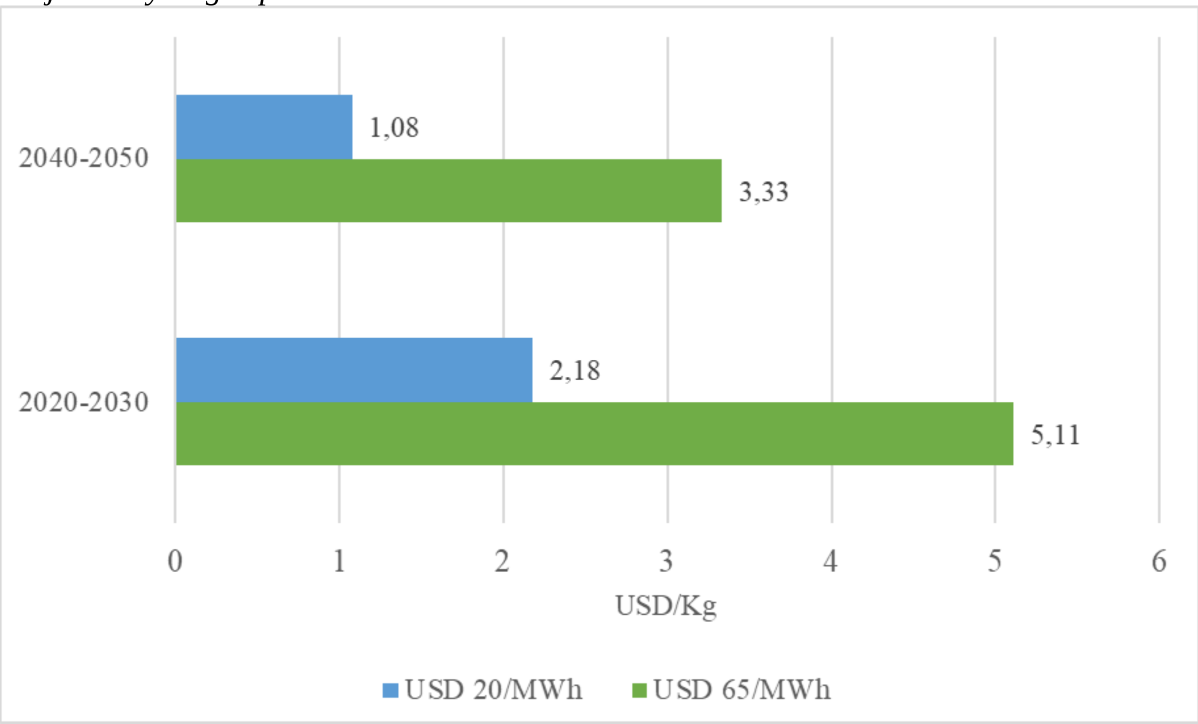


Source: IRENA (2020a)

In parallel, according to IRENA (2020b), achieving the economic feasibility of producing green hydrogen depends on three crucial factors: the capital expenditure of the electrolyser, the levelised cost of renewable electricity utilized in the process, and the annual operating hours (load factor).

Figure 2-22 illustrates that the production of green hydrogen can be economically feasible and competitive with blue hydrogen (which is produced from natural gas with captured emissions) by 2030, using affordable renewable electricity priced at approximately USD 20 per megawatt-hour (MWh). The report also suggests that if there is rapid expansion in the next ten years, the cost of green hydrogen will continue to decrease to below USD 1.5 per kilogram (kg).

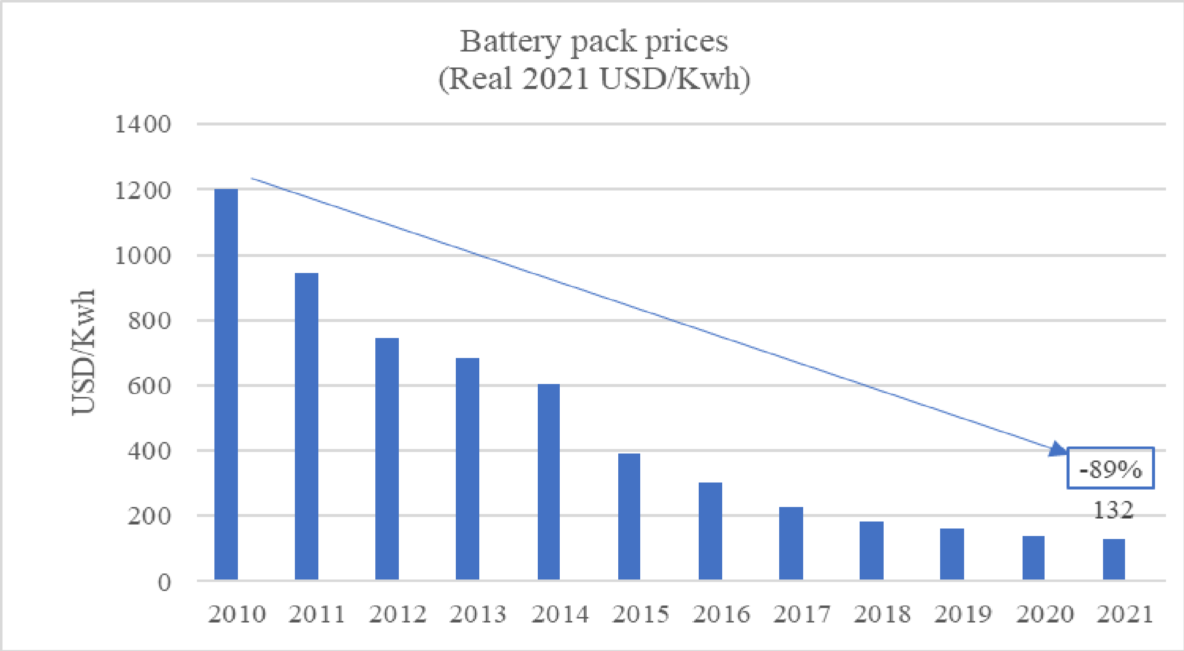
Figure 2-22
Projected hydrogen production costs.



Source: IRENA (2020b)

Furthermore, BloombergNEF (2022a) has also released the findings of its Battery Price Survey, which has been a significant industry benchmark since 2012 and offers data on battery costs since 2010. The survey, illustrated in Figure 2-23, shows a remarkable decrease in battery prices, with the volume-weighted average battery pack declining by 89% between 2010 and 2021, reaching a cost of USD 132 per kilowatt-hour (kWh) in 2021.

Figure 2-23
Lithium-ion battery cost reduction.



Source: BloombergNEF (2022a)

As previously noted, advancements in technology have played a critical role in the decreasing costs of all renewable energy solutions mentioned. This shift towards cost-effectiveness has provided significant options for transitioning the economy towards low-carbon production and consumption, in our opinion.

3 THE STATE OF THE ART

3.1 Literature review

i. Context about climate finance-related research

Only in recent decades have the academic literature and practitioner reports recognised climate change as a fundamental issue. Until the middle of the 20th century, climate studies were predominantly a discipline compiling regional statistics.

The interaction of different scientific disciplines only began in the 1960s and 1970s, with concerns about climate change. The United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) jointly founded the Intergovernmental Panel on Climate Change (IPCC) in 1988, which initiated a fully integrated interdisciplinary cooperation. To provide governments with information that they could use to develop climate policies, the reports of the IPCC relied heavily on computer modeling and assessments of the science behind climate change (Weart, 2013).

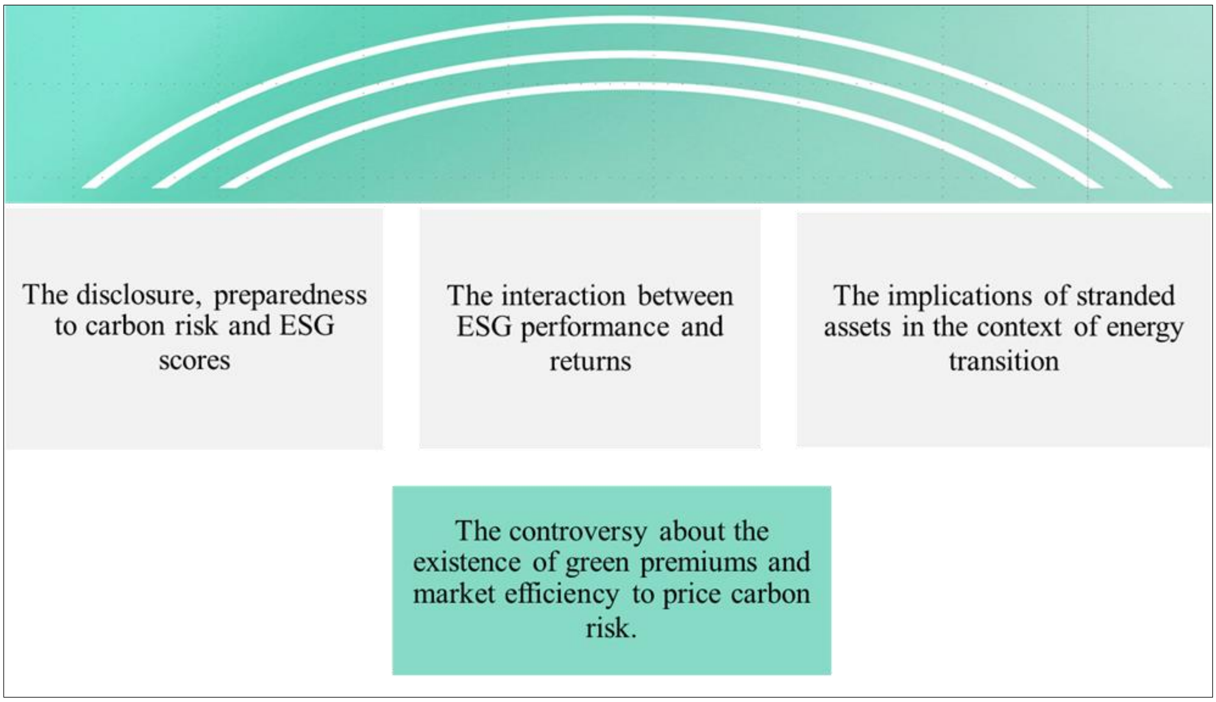
William Nordhaus was awarded the 2018 Nobel Prize in Economics for his contributions to integrating climate change into long-term macroeconomic analysis in the 1970s., which was a landmark in terms of interpreting interactions between society, the economy, and climate change. The economics of climate change follow his carbon tax proposition, which models climate risk as a global externality delivering carbon emissions that are to be internalised to achieve economic efficiency.

His pioneer studies (Nordhaus, 2019, 1977) of climate economic models also recognise the research opportunity that exists for financial economists to assess the risks associated with climate change as a global externality. Although climate change has been extensively covered in leading climate change journals such as Nature Climate Change, Climatic Change, and Global Environmental Change, Diaz-Rainey et al. (2017) research findings suggest that finance and business journals have had limited engagement with climate-related and climate finance-related research. Notably, the top three journals in finance - Journal of Finance, Review of Financial Studies and Journal of Financial Economics - only recently began covering this field.

ii. Linked areas of interest covered by current literature

In our review, we have identified several related areas of interest already covered by current literature and connected with our research: (a) the disclosure, preparedness to carbon risk, and ESG scores; (b) the interaction between ESG performance and returns; (c) the implications of stranded assets in the context of the energy transition; and (d) the controversy about the existence of green premiums and market efficiency to price carbon risk.

Table 3-1
Areas of interest covered by current literature



(a) A relevant set of research is focused on disclosure, preparedness for low carbon transition, and ESG scores:

In the study conducted by Castelo et al. (2012), we find a multicriteria analytic hierarchy process (AHP) to evaluate the level of exposure to carbon risk among a selected group of oil companies. The study identified both proactive and reactive companies in minimising their level of exposure, with a particular focus on energy efficiency and resource funding indicators. The research concluded that only those companies covered by the European Union ETS are currently facing a carbon risk.

Amel-Zadeh (2018) proposes a distinct viewpoint, stating that inadequate disclosures by companies contribute to the difficulties of assessing climate change impacts, while also making it challenging for investors to recognize and estimate risks. Similarly, Ilhan et al. (2019) examined the effects of portfolio firms' climate risk disclosures on global institutional investors. According to their survey, many investors consider that climate risk disclosures need to be improved and that firm-level reporting should be required and standardised.

Furthermore, Shaw and Donovan (2019) proposed a methodology to identify strategic differences among major international oil and gas companies in transitioning towards a low-carbon energy future. Their multidimensional analysis generates relative scores for the largest publicly traded oil and gas companies in terms of their preparedness for the energy transition. The research shows that the companies' declared strategic objectives and recent actions can provide investors with valuable insights into the various degrees of strategic options pursued.

Another subset of research has been focused on uncertainty regarding ESG scores and ratings and their impact on sustainable investing decisions. ESG scores and ratings use quantitative and qualitative data to measure the level of commitment to managing ESG risks, but methodologies, scope, and coverage of reports and qualifications vary greatly between providers of scores and ratings.

In their study, Berg et al. (2019) examined data from six notable ESG rating agencies - Moody's ESG (Vigeo-Eiris), S&P Global (RobecoSAM), Sustainalytics, KLD, Refinitiv (Asset4), and MSCI - and observed a broad range of correlations between the ratings, ranging from 0.38 to 0.71. To address the inconsistency, they categorized the various approaches into three categories: measurement, scope, and weights. While measurement relates to the method of measurement, scope and weights represent what an ESG rating aims to quantify. The results showed that 56% of the difference is due to measurement, 38% to scope, and 6% to weights assigned to individual components of the overall score. Thus, the study's findings indicate that the difference in ESG ratings primarily arises from a discrepancy in underlying data rather than differences in definitions.

Another first step towards a better understanding of the impact of ESG rating disagreement on stock return is provided by Gibson et al. (2020), who compared the ESG scores from six relevant data providers among S&P 500 firms (Sustainalytics, MSCI, Thomson Reuters, Bloomberg, KLD, and Inrate). The study demonstrated that the average correlation among the six providers' ESG ratings is less than 0.5. They also found evidence, for the environmental rating, of a positive relationship between rating disagreement and stock returns, while for corporate governance and social disagreement, this leads to the overvaluation of firms and thus lower subsequent stock returns. The authors suggest caution to investors who rely on one single data provider for the ESG ratings or overlook ESG rating disagreements.

Avramov et al. (2022) found that due to the uncertainty surrounding ESG scores, investors are less inclined to invest in ESG and engage in ESG issues with companies. This could result in an increase in the cost of capital for low-carbon businesses, limiting their ability to make socially responsible investments and have a tangible social impact.

(b) The interaction between ESG performance and returns is covered by another set of research:

Atz et al. (2021) explained that the reason for the ambiguity surrounding whether corporate sustainability and ESG investment strategies improve financial performance prior to 2015 was due to variations in the research's focus and methods for addressing causal inference. Their meta-analysis revealed strong evidence that corporate sustainability has contributed to financial performance since 2015 (60% ± 7.5 percentage points, significantly higher than half). However, they found fewer favorable outcomes from an investor's perspective (38% ± 6.1 percentage points), consistent with prior meta-analyses. Thus, their review upholds the distinction between corporate and investor studies published before and after 2015.

In this context, it is worth mentioning previous research conducted by Lee and Faff (2009) that suggests financial markets do recognize the value of Corporate Social Performance (CSP) information. However, they argue that current asset pricing models are inadequate in fully capturing the influence of CSP on security valuations. Conventional asset pricing models suggest that only systematic risk is important, with expected returns being a function of this risk alone, and idiosyncratic risk not being priced. The authors further analyse the data and found that the leading CSP portfolio performs worse than its lagging counterpart, which is contrary to the extensive research that supports a positive correlation between CSP and financial performance. They contend that higher returns for companies lagging in CSP offset the increased idiosyncratic risk.

A related area of research provided by Hoepner et al. (2020) reveals that engaged shareholders can create value beyond returns, as exposure to a downside risk factor declines following a company's successful engagement. Their research also demonstrates that engagement from shareholders in ESG issues, particularly environmental concerns and climate change, can reduce a company's downside risk.

Corporate social responsibility issues (CSR) and financial performance in the energy sector are the focus of several studies. Amongst them, Pätäri et al. (2014) summarise their main findings thus: (a) the impact of CSR strengths and concerns on a company's financial performance varies; (b) the impact is contingent on the performance measure employed, such as profitability or market value; (c) the impact manifest after varying periods of time; (d) in most model specifications, there is no evidence that corporate finance performance Granger-causes corporate social performance. The authors conclude that CSR strengths and concerns should be viewed as separate constructs in empirical contexts.

Ayaydin and Thewissen (2016) provide evidence that corporate environmental performance and financial performance influence the market valuation of energy companies. Their research reveals that a portfolio strategy that takes long (short) positions in energy firms with strong (weak) environmental performance yields an annual abnormal return of 9.624% after controlling for the Carhart (1997) four factors model. However, the performance of both portfolios for non-energy firms is statistically insignificant.

The theoretical equilibrium model developed by Pastor et al. (2021) suggests that asset pricing is based on both market and ESG (or green) factors. According to this model, green stocks are likely to have lower expected returns due to ESG investors' preferences and the fact that green stocks help to hedge climate risk. Additionally, green and brown stocks have contrasting exposures to an ESG (or green) risk factor, which reflects sudden changes in the ESG concerns of investors and customers. For this reason, unanticipated changes in consumer or investor demands during a specific period would cause green stocks to outperform brown stocks at that time.

(c) The implications of stranded assets in the context of energy transition

Stranded assets can be identified as assets that are at risk of becoming obsolete due to premature or unanticipated impairments, write-offs, or due to regulatory or policy changes being translated to liabilities. In our particular context, they are assets that given the changes related to the energy transition, may be worth less than expected.

Since 2016, the European Systemic Risk Board (ESRB, 2016), an agency of the European Central Bank, has considered two possible transition scenarios to a low-carbon economy: (a) a benign scenario, occurring gradually, in which repricing of carbon assets likely does not represent systemic risks; and (b) an adverse scenario in which the transition occurs late and abruptly, so that could result in constraints on the use of carbon-intensive energy sources.

Their main concern is that the reserves of fossil fuels, currently on the fossil fuel companies' balance sheet, would need to remain unexploited to avoid climate risks. If there is an abrupt collapse in their asset valuations, caused by climate policy enforcing the write-off of large fossil fuel assets, it could trigger systemic effects in the financial markets.

Similarly, in 2017, the Task Force on Climate-related Financial Disclosures (TCFD, 2017), a body created by the Financial Stability Board, developed recommendations for more effective climate-related disclosures designed to assist companies in providing better information to support informed capital allocation. This was well-valued by investors in carbon-intensive sectors, particularly concerned with potentially stranded assets.

Within this context, Atanasova and Schwartz (2019) analysed oil and gas reserves in North American companies for the period 1999 to 2018. Their findings indicated that although these reserves were a crucial factor in determining the firms' value, an increase in reserves had a negative impact on the value of the firm. Notably, this effect was mainly attributed to the growth of undeveloped reserves and was more pronounced in countries with strict climate policies. This outcome supports the idea that markets discourage investment in the expansion of undeveloped reserves due to the potential climate policy risks. Furthermore, the study's outcomes demonstrated that the correlation between the expansion of undeveloped oil reserves and the decrease in firm value remained unaffected by both analyst coverage and stock market liquidity.

On the other hand, Yergin and Pravettoni (2016) argued against the existence of a financial stability risk arising from potential steep declines in the valuation of oil, gas, and coal companies. Their research found that the majority (approximately 80%) of the value of publicly traded oil and gas companies is tied to prove reserves that will be produced and monetized over a 10-15 year period. This time frame is considered too short for a significant energy transition to occur. To provide context, during the period of June 2014 to December 2015, when oil prices collapsed, a total of 82 oil and gas companies worldwide lost 42% of their market value, which amounted to a market capitalization loss of $1.4 trillion. Nevertheless, this occurrence had no significant impact on the global financial system as a whole.

The Carbon Tracker Initiative, an independent financial think tank, represents the first attempt to estimate the amount of stranded assets of listed companies to comply with the targets established in the Paris Agreement. Their recent studies (Carbon Tracker, 2021) highlight to investors who choose not to align with the net zero emissions by 2050 objective, as defined by the IEA (or other 1.5°C scenarios), that asset stranding is still a major risk under slower transition pathways, albeit in the form of investment on unsanctioned assets. They remark also on the importance of investors continuing to put pressure on companies for more serious transition planning.

With all of this in mind, there is still an open debate regarding the creation of potentially stranded assets that could destroy shareholder value while, at the same time, providing sustainable and affordable energy to society. For instance, Goldman Sachs (2022c) highlights how the oil and gas sector is facing structural underinvestment due to factors such as the high cost of capital, regulatory uncertainty, and a lack of global coordination. This situation has led to rising price inflation and concerns regarding affordability. The question has become more central to the debate due to the spike in commodities prices and energy costs in the aftermath of the COVID-19 pandemic.

Following more recent research, Goldman Sachs (2022b) reports that the Russian invasion of Ukraine is a turning point for the energy sector. According to the authors, the current emphasis on diversification, energy security and resilience will lead to a new energy investment scenario, which is predicted to rise above the historical peak of US$2 trillion per year by 2024 to support global rising energy needs. This suggests that the forthcoming energy investment era will prioritize increased investment in renewable power and network infrastructure, as well as traditional fuels, particularly natural gas (LNG). The latter is necessary to ensure an affordable and more resilient energy transition.

(d) The controversy about the existence of green premiums and market efficiency to price carbon risk is another relevant issue covered by the literature:

The term “green premium” or “greenium” is used as a measure of the added value of environmentally friendly activities (“green”) meaning excess market returns. The term “carbon risk premium” relates to the compensation that investors may seek for keeping stocks with high exposure to CO_2 emissions. In this context, we can highlight two main research areas.

On one hand, there is controversy surrounding their very existence. Some authors have found that there is a carbon premium, while others indicate that there is not; still, other researchers report having found evidence that it exists but that it is negative. The presence of a carbon risk premium can be explained by the fact that there is a positive relationship between a firm's CO_2 emissions and its stock returns in the cross-section, which may be due to investors seeking compensation for keeping the stocks of high CO_2 emitters and being exposed to related higher carbon risk. A subset of this subject is whether it is a systematic risk factor – as could be interpreted from global and uniformly applied regulatory interventions, such as carbon taxes

– or a non-systematic risk factor (idiosyncratic), when such interventions or technological advances happen in different sectors or different regulatory levels, rather than globally.

Another research area relates to the possibility of the current market inefficiency concerning climate risk pricing, and therefore the risk associated with carbon emissions is underpriced, after controlling for other known risk factors in the literature, such as industry and firm characteristics. Thus, investors could achieve higher returns with appropriate investment strategies, or they could find that shares of green companies that provide better climate coverage have higher expected returns, rather than lower, as the theory explains.

We find that there is a degree of controversy in the literature about the green premium. Larcker and Watts (2019) observed that green bond securities, issued by the same issuers on the same day with non-green characteristics, were priced economically identically. Investors view green and non-green securities issued by the same issuer as nearly identical substitutes, as they are unwilling to sacrifice wealth for environmentally sustainable investments, even when the risk and payoff are constant and known to investors beforehand. Thus, the authors conclude that the “green premium” is essentially zero.

In their research of carbon risk in global equity prices, Görgen et al. (2020) found that while carbon risk can explain systematic return change, there is no evidence of a risk premium associated with it. This suggests that investors may not seek rewards for bearing carbon risk. The authors propose that one reason for the lack of pricing could be due to investors' inability to accurately quantify or predict carbon risk. They also suggest that the carbon risk of green and brown firms is better explained by unpriced changes in the evaluation of the firm´s cash flow channel rather than the priced discount-rate channel.

Alessi et al. (2019) conducted a study on the European stock market and found highly significant evidence of a negative green risk premium, or "greenium." They suggest that investors are willing to accept lower compensation, all else being equal, for holding assets that are positively correlated with greener assets. To overcome the issue of greenwashing, the authors created a synthetic greenness index for each stock using company-level information on greenhouse gases or CO_2 emissions intensity per sale, along with a measure of the completeness and transparency of such information. They argue that failing to price the greenium may result in losses for investors and European large banks, even in a benign scenario. This highlights the need for carbon stress tests for systemically relevant banking institutions.

Bolton and Kacperczyk (2021a) present a contrasting view, as they find evidence of a significant "carbon premium" in the US stock market. They observe that firms with higher total carbon emissions and changes in emissions generate higher stock returns. However, they do not find any carbon premium linked to emissions intensity. Their study indicates that investors are factoring in carbon risk and require compensation for being exposed to idiosyncratic risk factors associated with climate risk. In addition, their study shows that the carbon risk premium they find cannot be attributed to divestment effects from large investors.

In a subsequent study, Bolton and Kacperczyk (2021b) found that a carbon premium exists in global stock markets, with firms that have higher emissions compensating investors with higher returns. They argue that there are currently no models available to effectively capture carbon-transition risk, but their findings demonstrate that the carbon premium exists across all sectors, not just in the coal, oil, and gas industry. Moreover, the carbon premium is positively correlated to both the level of emissions and the percentage change in year-to-year emissions, while controlling for characteristics that explain returns. The authors provide evidence that the carbon premium is not solely driven by unexpected return components and highlight the importance of the discount rate channel in carbon risk premia. Additionally, their findings suggest that divestment is not the only reason for the carbon premium.

A recent sectorial study conducted by Imperial College Business School and IEA (2021) provides an alternative perspective, revealing that renewable power companies offer a superior risk and return profile, both during normal market conditions and in the face of recent market downturns. Their findings show that investing in a portfolio of renewable stocks instead of a portfolio with fossil fuel stocks can lead to greater diversification, as renewable stocks have a lower correlation with the global market, particularly during market downturns. The authors employed the Fama-French five-factor model to elucidate the average stock return of each portfolio, taking into account the size, value, profitability, and investment effects. The study found that the global renewable portfolio did not exhibit a significant factor bias, except for negative loadings on the profitability and conservative investment factors.

In line with the studies focused on explaining the portfolio's exposure to climate change, Gimeno and González (2021) constructed a green factor based on companies' carbon footprint, showing a trend in financial markets towards favouring companies with a lower carbon footprint in comparison to those with a higher carbon footprint, measured in tons of CO_2 equivalent emissions per income in million US dollars, to control for the company sizes. The authors constructed this factor as "Green minus Polluting" companies (GMP) and explain stock market returns to a higher extent than benchmark factors such as "Winners minus Losers" (WML) by Carhart (1997), and the two factors added by Fama and French (2015), the "Conservative minus Aggressive" (CMA) or "Robust minus Weak" (RMW) factors, and in line with the three-factor model of Fama and French (1993). The authors argue that regardless of whether the reason behind this investor preference for green stocks is a result of a projection of their better future performance in the transition to a lower carbon economy or due to their proactive engagement in the fight against climate change, the outcome is driving up the prices of green stocks.

In contrast, a study by Hsu, Li, and Tsou (2022) reveals an average annual return of 5.52% in a long-short portfolio created from companies with high versus low levels of toxic emission intensity, that is measuring emissions over book equity. The observed return spread cannot be accounted for by systematic risk factors. To account for the pollution premium observed, the authors construct a general equilibrium asset pricing model, in which the cash flows of firms are influenced by the uncertainty surrounding policy regime changes in environmental regulation. The study indicates that the return spread cannot be attributed to traditional risk factors, including the five-factor Fama-French model. In addition, Fama and MacBeth (1973) regressions validate the positive correlation between toxic emissions and stock returns.

Another relevant area pertinent to our research is the pricing of climate-related risks. A review of the literature reveals that climate risk premium does not seem to be completely priced by the market, suggesting the possibility of market inefficiencies in assessing carbon risk. As a result, investors may be able to attain greater returns by implementing appropriate investment strategies.

In relation to this subject, Jiang and Weng's (2019) research employs the long-term climate index, known as the Actuaries Climate Index (ACI), as a proxy for climate change risk in the United States and Canada. Companies located in areas with higher climate change risk tend to experience poorer financial outcomes, and greater ACI trends predict less profitability for relevant firms. This inspires the authors to further test the predictability of ACI trends on stock returns. The study finds that a long-short stock strategy can result in positive returns over a one-year holding period during a 26-year testing period with zero costs, indicating that the stock market may be inefficient in its response to climate change risk.

Specific sector research conducted by Bernardini et al. (2021) investigate the impact of carbon risk on the stock returns of European electric utilities. Their findings suggest that a low-carbon premium exists, which has been statistically significant since 2012. This premium may be interpreted as an additional return earned by companies with a larger share of low-emissions gas plants in their energy mix, once the market has perceived and priced in their lower risks.

The study demonstrates that by concentrating on their low-carbon company sample, investors could have achieved greater returns without altering the overall risk profile of their investment strategy.

According to Pastor et al. (2022), the equity "greenium" in the US market can be estimated by comparing the implied costs of capital of green and brown stocks. Their findings indicate that the greenium was consistently negative, supporting the argument that the better performance of green stocks in the US during the sample period was unexpected. Despite the high returns of green assets, the study suggests that this performance was due to the unexpected increase in climate concerns, rather than high expected returns. To demonstrate that US green stocks performed better than brown stocks as climate concerns intensified, the authors constructed a green factor that measured the differences in return between climate-friendly and unfriendly stocks. They found that the positive performance of the green factor disappeared without climate-concern shocks.

A subset of research in this field is related to the uncertainty surrounding the evolution of the European Union´s Emissions Trading System (ETS) and its potential implication on stock performance.

For example, Oberndorfer's (2009) research reveals a statistically significant, albeit minor, positive correlation between the price of emission permits and stock prices.

Similarly, Veith and Zimmermann's (2009) findings indicate a weaker connection for companies that require a higher volume of permits due to increased electricity production. The authors emphasize the impact of ETS prices on stock returns, which is linked to the potential for additional profits from the freely granted sale of permits in the initial phase and the ability to pass on permit acquisition costs to customers.

With a particular focus on utilities, Koch and Bassen (2013) establish a statistically significant correlation between ETS future prices and stock performance for only four out of

20 European electric utilities. Interestingly, three of the four are part of the high-intensity emission group and enjoy the advantage of the risk premium associated with carbon risk that is closely tied to the rise in ETS price.

In another study regarding the implications of carbon emissions and ETS on the return of German firms, Oestreich and Tsiakas (2015) found that investing in carbon-intensive companies resulted in a significant additional return. The authors argued that the carbon premium arises from various sources, including the additional cash flows generated by increasing sale prices to fund ways to reduce carbon emissions, profits from the sale of surplus ETS permits, and the premium required by the market to manage carbon risk.

iii. The research gaps

Our research aim is to identify and measure the existence of a "green factor" or, conversely, a "carbon transition risk" that reflects the transition of energy companies to a lower carbon ("green") business, and whether that green factor may explain the stock returns for energy companies and particularly oil and gas companies.

For this reason, we reviewed in more detail the literature addressing the theme comprising climate change finance and the extent to which investors are pricing carbon risk into the asset values, with a specific emphasis on energy companies. There are several global or multisector studies about the linkage between carbon transition risks and financial returns by authors such as Oestreich and Tsiakas (2015), Jiang and Weng (2019), Alessi and Panzica (2019), Görgen et al. (2020), Bolton and Kacperczyk (2021a, 2021b), Hsu et al. (2022), Gimeno and González (2022), and Pástor et al. (2021 and 2022).

Nevertheless, only a few studies are based on a sectorial basis, such as that by Bernardini et al. (2021), who focus on the effect of carbon risk on the stock returns of European electric utilities, while Shaw and Donovan (2019) introduce a methodology for identifying strategic differentiation among major international oil and gas companies in the context of the energy transition. Similarly, Ayaydin and Thewissen (2016) analyse the relationship between environmental performance and financial reward in the energy sector. A study by Jiang and Weng (2019) analyses agriculture-related stocks and climate change risks while the portfolios of power renewable stocks and fossil fuel stocks are analysed by Imperial College Business School and IEA (2021).

Another area on which the literature does not converge regards the indicators of the carbon risk premium and the market efficiency to price green stocks, where we find a controversy between different authors, as mentioned previously. Also, as evidenced by Venturini (2022) in his review of the literature on climate change, risk factors, and stock returns, few studies have investigated how firms can best adapt to these risks.

To the best of our knowledge, there are remaining gaps in the current literature, with insufficient evidence of how the financial performance of the energy sector may be affected by the transition to a lower-carbon economy. In particular, it would be of interest to know, when we compare oil and gas companies with others, such as cleaner energy companies, whether there is an impact on their shares return and their equity cost of capital. According to the IPCC Sixth Assessment Report (IPCC, 2021), the largest individual sector contributing to global greenhouse emissions is the energy sector. Therefore, in our view, further focused studies can provide insights into how this sector can also be part of the solution to achieve a lower-carbon economy.

Our research aims to shed some light on whether, and to what extent, earlier measures and the higher speed taken by some energy companies to adapt to a lower-carbon business mix may result in better financial performance.

3.2 Mapping Transition Risk: Climate-friendly investments, regulation and shifting investor preferences

Our approach is based on the framework proposed by Semieniuk et al. (2021), which outlines the drivers of carbon transition risk that can impact the equity markets. These drivers are a combination of three factors: policy risk, technology risk and preference change.

Policy risk refers to the potential risks and opportunities that may arise due to climate mitigation policies; technology risk relates to the emergence of cost-effective technologies that may accelerate the introduction of low-carbon energy sources; and finally, preference change relates to unanticipated shifts in the customers and/or investor preferences for green assets.

In this section, we aim first to describe the evolution and outlook for climate-friendly investments that also involve the related technological challenges, and secondly, climate mitigation policies and regulations developed in the USA and the European Union, which are the main geographical areas covered in our research. Finally, we provide an insight into whether investors are signaling a preference for greener energy companies and, with all these elements, we will conduct a preliminary transition risk assessment of a selected group of companies within the energy sector.

i. Climate-friendly energy investments and technology evolution

A remarkable analysis to understand the most recent outlook on energy transition is the Net Zero Roadmap by 2050 report, published by the International Energy Agency (IEA) in May 2021 (IEA, 2021c).

This report was prepared to inform the 26th Conference of the Parties (COP26) of the United Nations Framework Convention on Climate Change held in Glasgow in November 2021. It aimed to highlight the need to strengthen the ambition and action plan to achieve the 2015 Paris Agreement targets, with a new scenario, the Net Zero (NZE), that does not rely on emission reductions outside the energy sector and is more ambitious than previous ones; such as:

a) the Stated Policies Scenario (STEPS) considers only the explicit policies that are currently implemented or have been announced by governments.

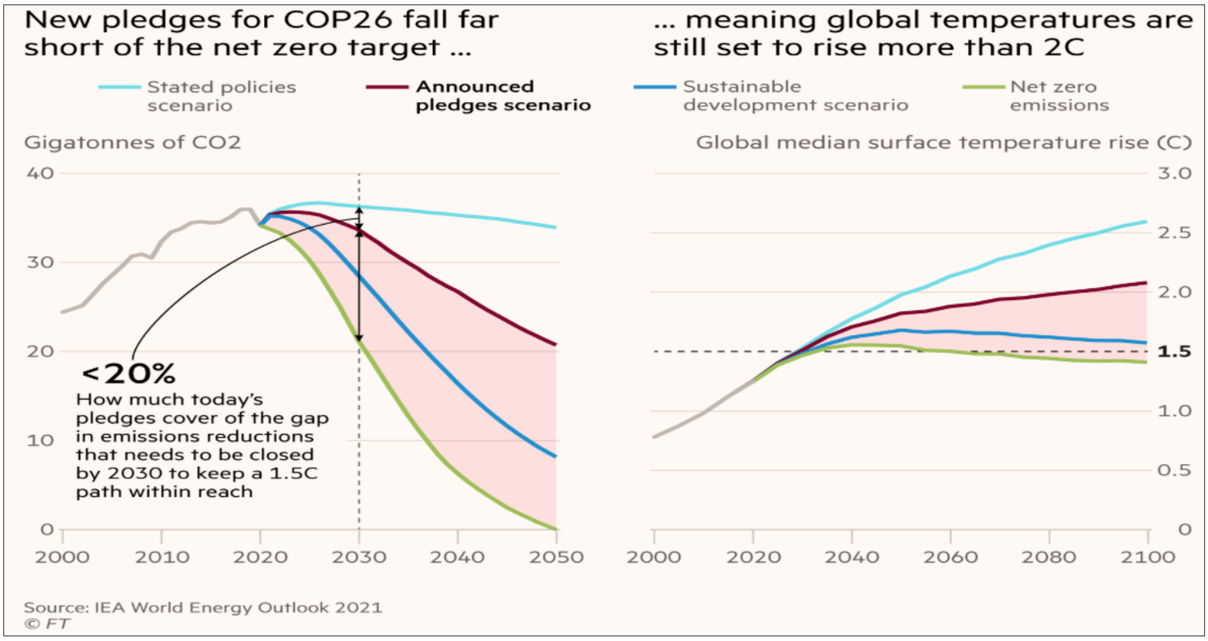
b) the Announced Pledges Case (APC) assumes that all declared national net zero commitments will be met in full and on schedule, independently they are currently backed or not by specific policies.

c) the Sustainable Development Scenario (SDS) is based on clean energy investments and policies aligned with the key Sustainable Development Goals (SDG). This scenario assumes that all existing net zero commitments will be achieved in full and significant efforts will be made to achieve near-term emission reductions; amongst them, it is assumed that advanced economies will reach net zero emissions by 2050, China around 2060, and the rest of all other countries by 2070 at the latest.[14]

Journals (Financial Times, 2021) have acknowledged the relevance of the NZE report (see Figure 3-1), as it presented the clear message that previous scenarios were not enough to reduce global CO_2 emissions to net zero between now and 2050, in line with a 50% likelihood of remaining within 1.5 degrees of warming by 2100. There is a significant gap of approximately 20% in emissions reduction required by 2030 if considering only the APC, which means that global planet temperature is at risk of rising more than 2 degrees.

[14] For a detailed description and objectives for each scenario see IEA at https://www.iea.org/reports/world-energy-model/understanding-weo-scenarios#abstract

Figure 3-1
The work that remains to reach net zero



Source: Financial Times (2021)

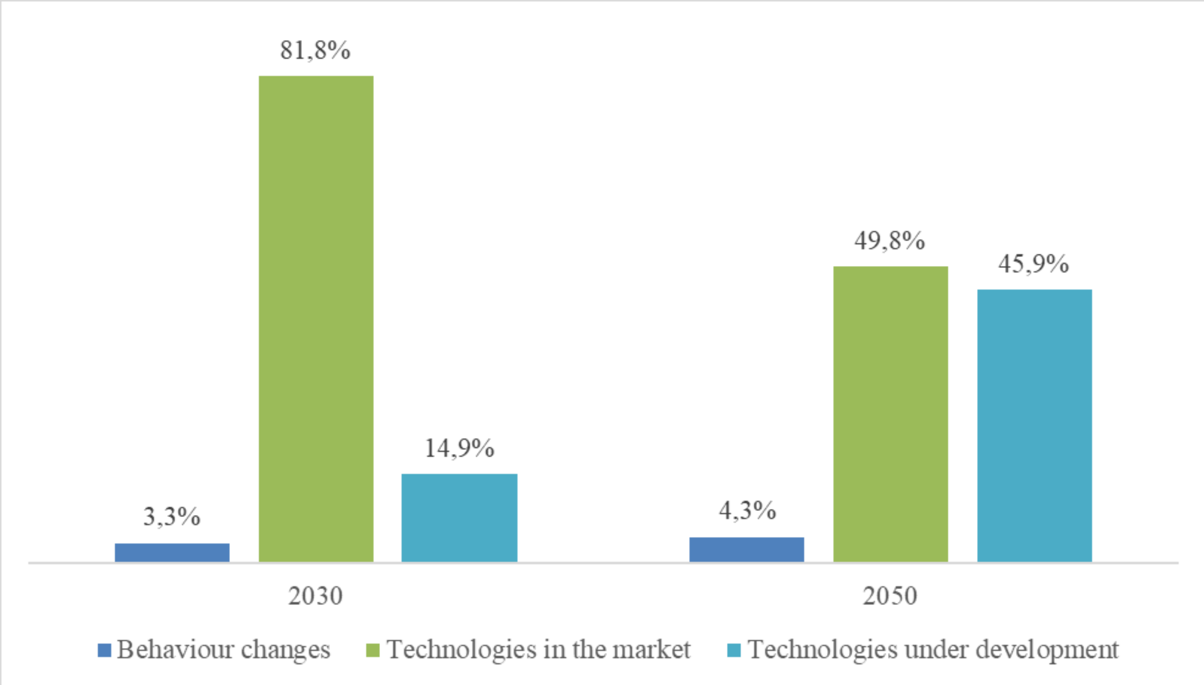
In the short term, the IEA report describes an NZE that, in summary, requires:

- increased dissemination of all clean and efficient energy technologies available
- a significant effort to accelerate innovation, and
- no additional investments in new fossil fuel supply projects from now on.

In the words of the IEA, the agency recognises that "there are many possible paths to achieve net-zero CO_2 emissions globally by 2050 and many uncertainties that could affect any of them; the NZE is, therefore, a path, not the path to net-zero emissions. Much depends, for example, on the pace of innovation in new and emerging technologies, the extent to which citizens are able or willing to change behaviour, the availability of sustainable bioenergy, and the extent and effectiveness of international collaboration" (pp. 49-50).

As a matter of reference, Figure 3-2 shows the technological uncertainties in the NZE. The majority of the CO_2 emissions reductions expected globally until 2030 will be achieved through currently available technologies, but by 2050, close to 50% of the reductions are anticipated to originate from technologies that are currently in the prototype or at the demonstration phase, such as bioenergy, clean hydrogen and carbon capture, utilisation, and storage (CCUS).

Figure 3-2
Annual CO_2 emissions savings in the NZE compared to 2020



Source: IEA (2021c)

In the NZE the total energy supply mix is very much different from today. In 2020, oil represented 30% of the total energy supply, while coal 26% and natural gas 23%, which means 79% came from fossil fuels. By 2050, there will be a substantial shift to renewables, which will provide two-thirds of the energy supply, split between, wind, solar, bioenergy, hydroelectricity, and geothermal.

To achieve the NZE there is a need to more than double annual investments in energy, from the global annual average of over USD 2 trillion between 2016-2020 to nearly USD 5 trillion by 2030 and to USD 4.5 trillion by 2050. More important, however, is the implication of a significant change in sectors and technologies (see Figure 3-3).

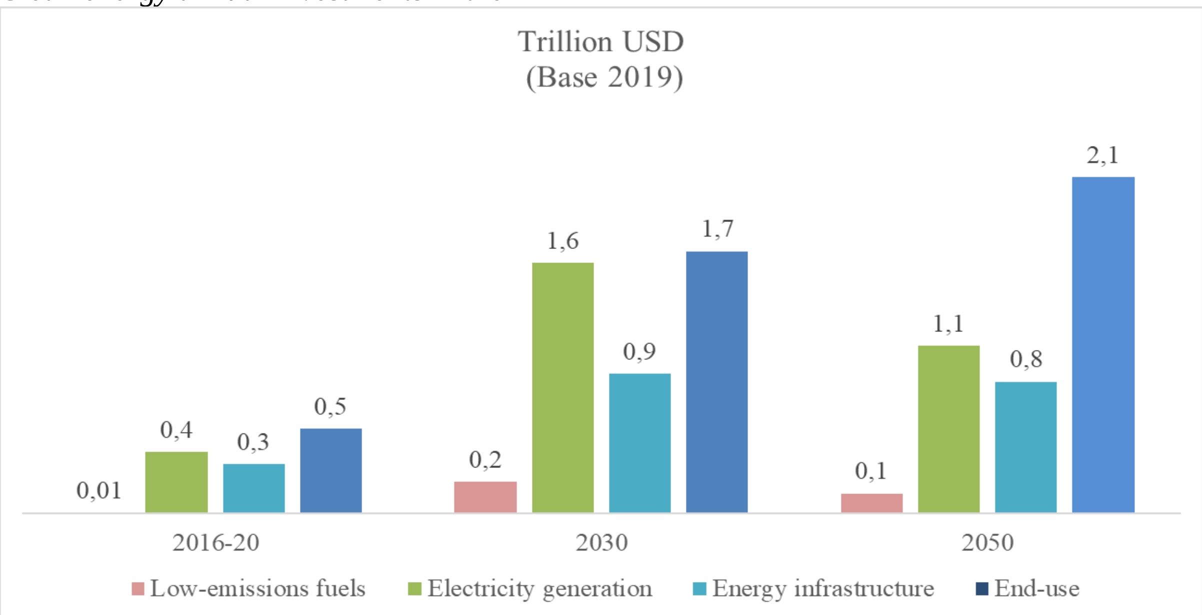
The main investment shift in the NZE is in electricity generation, where annual clean investments will rise from USD 0.4 trillion on average in 2016-2020 to USD 1.6 trillion in

2030, of which USD 1.3 trillion will be in renewables (the rest nuclear), falling to USD 1.1 trillion by 2050 because of lower renewable technology costs. The following shift is in clean energy infrastructure, which will increase from approximately USD 0.3 trillion in 2016-2020 to USD 0.9 trillion in 2030 and USD 0.8 trillion in 2050. Finally, investments in low-carbon technologies in end-use sectors will rise on an annual average from USD 0.5 trillion in the same period to USD 1.7 trillion in 2030 and USD 2.1 trillion in 2050. Precisely, under this item, the IEA incorporates in the NZE a wider scope of efficiency enhancements in buildings which differs from the reporting in the previous IEA World Energy Investment report (IEA, 2020a).

End-use investments include the deep retrofitting of buildings, the transformation of industrial processes, the acquisition of vehicles with low emissions, and investments in efficiency, such as those involved in enhancing the energy performance of equipment types relative to a conventional design.

In summary, out of the total investment increase in global energy, clean energy and efficiency will represent by 2030 and 2050 almost four times the annual average volume of the period 2016-2020.

Figure 3-3
Clean energy annual investments in the NZE



Source: IEA (2021c)

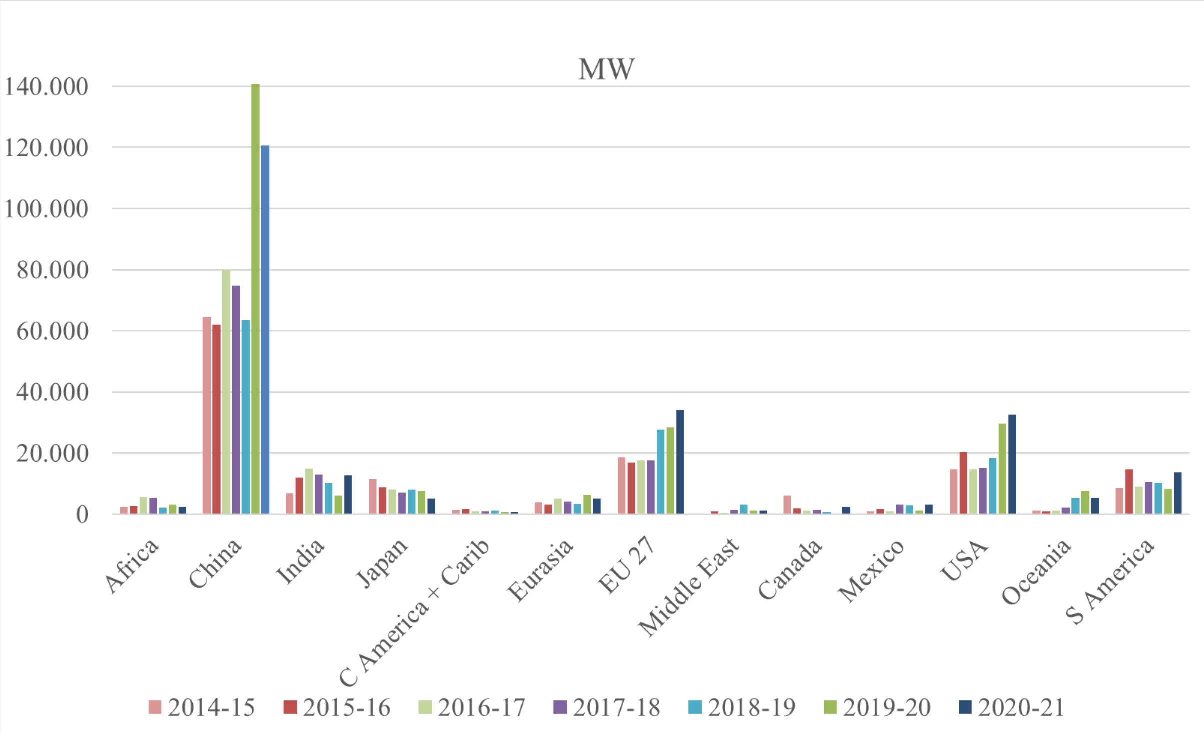
In terms of context with more recent figures, the evolution of investments in the global energy transition hit a record high of USD 755 billion in 2021, growing significantly from USD 312 billion in 2014 and USD 595 billion in 2020 (BloombergNEF, 2022b). Renewable energy technologies, excluding large hydropower, are the main component of these investment flows; nevertheless, the percentage of renewable energy transition technologies has decreased gradually from 2014, representing 90% of the global energy transition, to approximately 60% in 2020 as other technologies such as electrified transport and heating have attracted higher investments.

Focusing now on our research to transition towards clean energy generation, the NZE implies annual additions by 2030 of 630 gigawatts of solar PV, and 390 gigawatts of wind power, totalling 1020 gigawatts. Combined, this is approximately two times the record level of 248 gigawatts set in 2020, with 134 and 114 gigawatts of solar PV and wind power, respectively. For solar PV, this is equivalent to installing the world’s current largest solar park almost every day. All of that will represent a renewable share in the generation of electricity growth from 29% in 2020 to 61% in 2030 and 88% in 2050.

To put into context the enormous effort required to reach the NZE, we need to understand the global pathway followed until now, the relevance of the European Union and the USA's contribution during our period of analysis 2014-2021, and the regulatory framework developed by these two main jurisdictions under our scope.

According to IRENA (2022a) and as illustrated in Figure 3-4, the main additions of renewable power capacity to the global market come first from China, followed by the European Union and the USA, in similar amounts.

Figure 3-4
Installed renewable electricity capacity additions (2014-21)

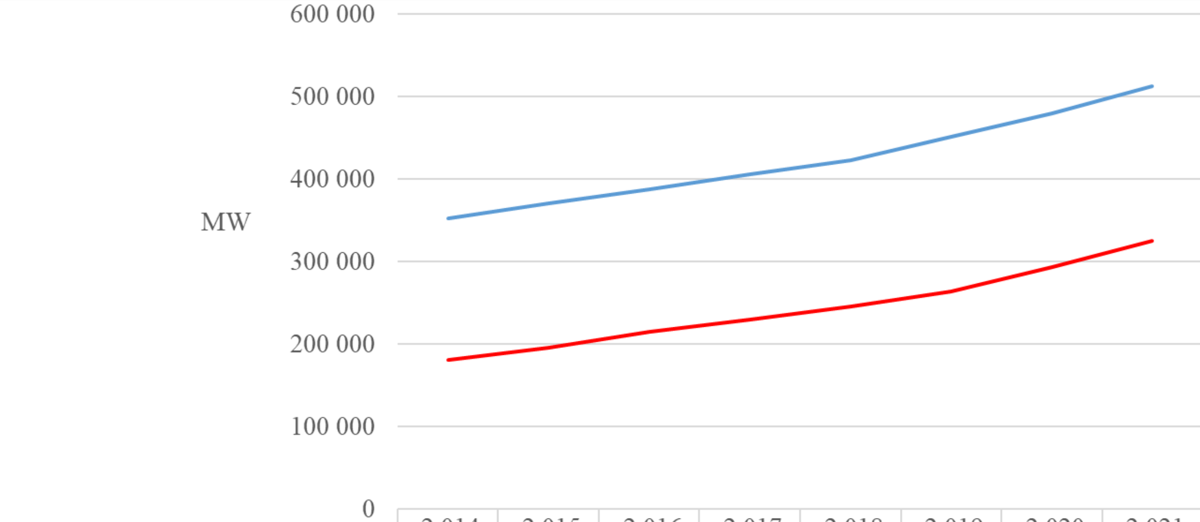


Source: IRENA (2022a)

The similar size of renewable capacity additions between the European Union and the USA is a remarkable finding that shows that, despite the higher market size of the USA in comparison with Europe, its relative renewable energy contribution is smaller. The total renewable energy capacity is provided in Figure 3-5 and the share of renewables concerning electricity capacity and generation in Figure 3-6, demonstrating that the EU contribution is significantly larger than that of the USA.

Figure 3-5

Renewable energy capacity in USA and EU27 (2014-21)

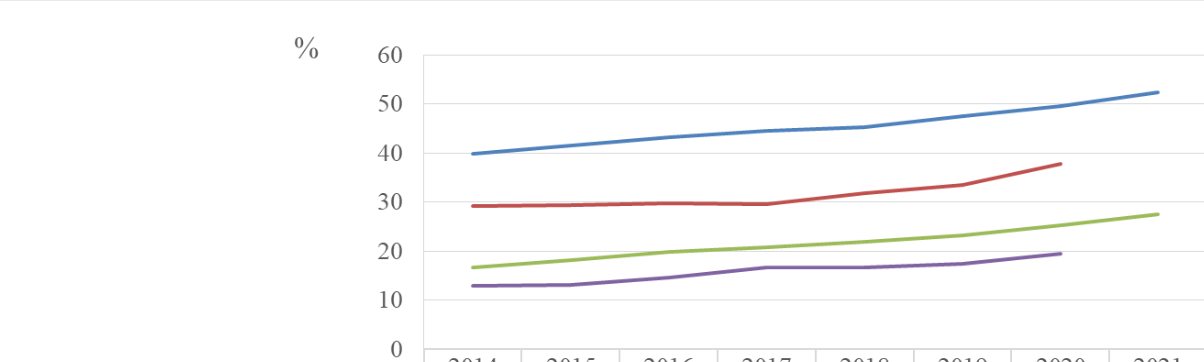


	2 014	2 015	2 016	2 017	2 018	2 019	2 020	2 021
Total renewable energy EU 27	352 553	371 010	387 890	405 557	423 140	450 729	479 196	513 097
Total renewable energy USA	180 309	195 046	215 233	229 824	245 026	263 324	292 949	325 391

Source: IRENA (2022b)

Figure 3-6

Renewable energy share of electricity capacity and generation in USA and EU27 (2014-21)



	2014	2015	2016	2017	2018	2019	2020	2021
EU share of electricity capacity (%)	39,93	41,58	43,19	44,57	45,34	47,48	49,68	52,49
EU share of electricity generation (%)	29,27	29,46	29,76	29,56	31,94	33,63	37,93	
USA share of electricity capacity (%)	16,78	18,18	19,80	20,88	21,89	23,34	25,33	27,46
USA share of electricity generation (%)	12,92	13,17	14,74	16,75	16,68	17,47	19,42	

Note: 2021 figures for electricity generation are not available at the time of the research

Source: IRENA (2022)

Considering all of these elements collectively, we can conclude that there is a material difference in the speed and deployment of cleaner energy sources, with that of the European Union being faster and greater than in the USA.

ii. Policy and regulatory landscape in the USA and European Union

Environmental and climate concerns have been on the international political agenda since the late 1960s and early 1970s. The USA is considered one the most consistent leaders, while the member states of the European Union have been identified as more laggardly, although this situation has changed since the 1990s, with the European Union emerging as a global environmental leader (Kelemen and Vogel, 2010).

On the other hand, some authors argue (Parker and Karlsson, 2018), that the leadership role of the USA has fluctuated over time reaching the peak at the United Nations climate conferences in Copenhagen (2009) and Paris (2015). However, the leadership landscape has been divided, and the USA has had to compete for its leadership position with other actors, including the European Union and China.

With this context in mind, and regardless of the predominance role of either the USA or the European Union in the fight against climate change, for the purposes of our analysis we can acknowledge that together they are a representative sample through which to analyse the influence of their energy transition policies.

(a) The European Union policy and regulatory framework

To identify the effects of the European Union energy regulation in our analysis period, we need to look back at when the European Council in March 2007 and the European Parliament in December 2008 adopted the first energy and climate change objectives for 2020. These aimed to reduce GHG emissions by 20% compared to 1990 levels (rising to 30% if the conditions are right), reach 20% of total energy consumption from renewable sources and make a 20% improvement in energy efficiency ("the 20-20 targets for 2020").

These energy and climate goals were incorporated into the EU energy strategy 2020 and adopted by the European Council in June 2010, with the view that contemplated investments require a long period of stable policies. The energy roadmap to reduce GHG emissions by 80-95% in 2050 was endorsed by the European Parliament in March 2012.

During Jean-Claude Juncker's EU Commission mandate (2014-2019), one of the priorities was to construct a resilient energy union with a forward-looking climate change policy, which, among other issues, would solve the fact that the EU had energy rules set at the European level, but in practice, it has 28 national regulatory frameworks.

The European Council reached an agreement in October 2014 on a climate and energy framework for 2030 ("the 2030 package"). This framework involved setting more ambitious targets and policy objectives for the EU between 2020 and 2030. The Council also endorsed additional measures to enhance energy security and decrease the EU's energy reliance on external energy sources for its electricity and gas supplies. The 2030 package agreed upon by the European Council included several targets and objectives, such as:

- a binding EU target to reduce GHG emissions by at least 40% vs. 1990 levels by 2030
- an indicative EU target to improve energy efficiency by at least 27% in 2030
- a binding EU target to ensure renewable energy consumption of at least 27% by 2030
- urgent support for achieving the existing target of 10% electricity interconnection for the Baltic states and the Iberian Peninsula, no later than 2020, with an objective to achieve a 15% target by 2030.

The adoption of new EU-level targets, which were not to be split among member states, marked a departure from the previous climate policy framework, which was based on national targets. This change was made as a compromise with member states who considered binding national targets to be an undue burden. To ensure the alignment of national energy plans with the broader EU strategy, a new governance mechanism was established (Rayner and Jordan, 2016).

Later in February 2015, the European Commission adopted a new EU energy strategy aimed at achieving secure, sustainable, competitive, and affordable energy built on the targets agreed upon in “the 2030 package”. Since its launch, it has published several packages of measures to ensure that the EU energy strategy is achieved.

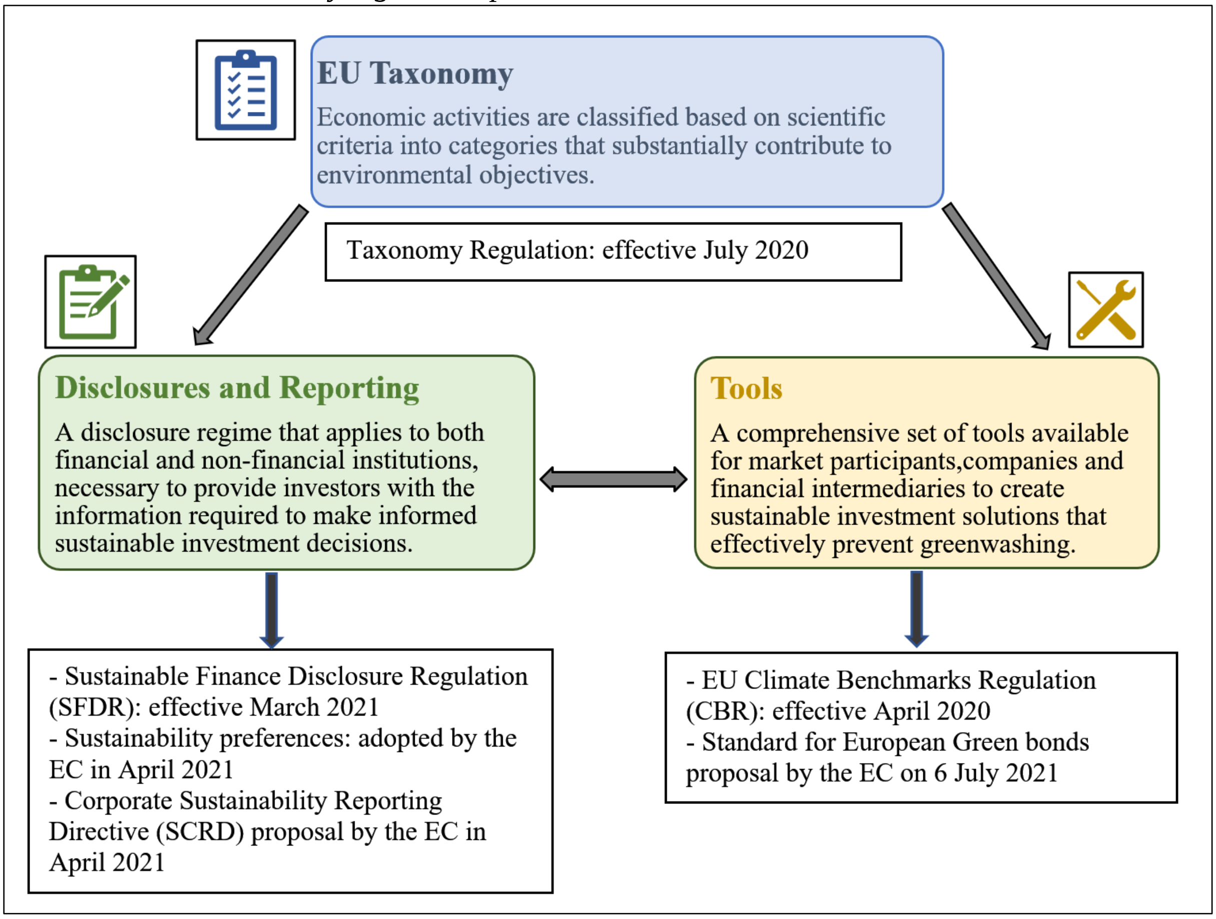
Conscious that the financial system plays a relevant role in channelling investments to a greener and more sustainable economy, the EU Commission appointed a High-Level Expert Group at the end of 2016 to provide a vision for the EU to develop a sustainable finance strategy. In January 2018, the expert group published its final report, and the EU Commission published in March 2018 the strategy outlined in the Action Plan on Sustainable Finance, aimed to achieve the following objectives:

- Redirect capital flows towards sustainable investment
- Promote transparency and encourage long-term thinking in economic and financial terms
- Address financial risks arising from climate change, environmental degeneration, resource reduction and social issues

To implement these objectives, the 2018 Action Plan has been evolving during recent years as described in Figure 3-7, with different effective time frames comprising the following key legislative pillars: 1)Taxonomy regulation, 2) Disclosure and Reporting legislation, 3) Climate Benchmarks regulation, and 4) Standard for EU Green bonds.

Figure 3-7

EU Action Plan 2018: Key legislative pillars



Source: European Commission (2021)

(1) The Taxonomy regulation, published in June 2020 came into force on July 12th of the same year, acknowledges economic activities that significantly contribute to the EU's climate and environmental objectives as "green" or environmentally sustainable. These activities must adhere to the principle of not causing significant harm to any of the environmental objectives and must satisfy specific social safeguards. However, it is essential to note that the EU Taxonomy is not obligatory for investors to use as a list of economic activities, nor is it a mandatory requirement for companies or financial products to meet specific environmental performance standards. Starting January 1st, 2022, the first two sustainable activities aimed at achieving climate and environmental objectives, namely mitigation and

adaptation, entered into effect. Moreover, on February 2nd, 2022, the Commission categorized nuclear and natural gas-related activities as transitional.

(2) The Disclosure and Reporting legislation focuses on two areas to enhance transparency:

i) For the financial markets participants and financial advisors, the Sustainable Finance Disclosures Regulation (SFDR) is in force from March 10th, 2021. It establishes disclosure obligations regarding the integration of sustainability risks in all investment processes ("sustainability risk policy") and for financial products that pursue the objective of sustainable investment. It also includes the disclosure obligations of investment decisions with adverse impacts and advice on sustainability matters. On January 1^{st,} 2023, the application of detailed disclosure requirements will begin and June 30^{th,} 2023 marks the first reporting deadline for principal adverse indicator KPIs at the entity level.

ii) For companies, the Commission's proposal for a Corporate Sustainability Reporting Directive (CSRD) on April 21st, 2021 aims to extend the scope of the current Non-Financial Reporting Directive (NFRD), which has been in force since October 22nd, 2014. The introduction of mandated EU sustainability standards by the CSRD requires the preparation of such standards by the European Financial Reporting Advisory Group (EFRAG). The first set of standards, based on the recommendations made by EFRAG, was due for adoption by October 31st, 2022.

(3) The Climate Benchmarks regulation entered into application on April 30^{th,} 2020. It creates two new labels or categories of climate-related benchmarks for financial market participants. The EU climate transition benchmark (EU CTB) generates a benchmark portfolio comprising assets of companies that pursue a decarbonisation trajectory, while the EU Paris-aligned benchmark (EU PAB), adjusts the resulting benchmark portfolio's carbon emissions to

align with the Paris Climate Agreement objective of limiting the global temperature increase to 1.5C° compared to pre-industrial levels.

The regulation also includes disclosures on how ESG factors are reflected in each benchmark. The Commission is still studying the possibility of introducing a new label, the ESG benchmark label, to provide more clarity to the market and help tackle ESG-washing, to be finished by December 31st, 2022.

(4) The Standard for EU Green bonds: the Commission adopted a legislative proposal on July 6th, 2021, on a voluntary standard mandating the use of proceeds for taxonomy-aligned activities; it is currently being negotiated by the European Parliament and the Member States. In its draft report, the European Parliament is envisaging mandating the standard for all bonds marketed as environmentally sustainable.

One of the Ursula van der Leyen Commission´s priorities for 2019-2024 set out a response to the climate and environmental-related challenges in December 2019 with the "European Green Deal", a vision for how to become the first continent climate-neutral and a plan for how to achieve EU neutrality by 2050. To reach this target, its roadmap represents a transformation of all sectors of the EU economy:

- Decarbonise the energy sector
- Support industries to innovate and become leaders in the green economy
- Renovate buildings for more efficient energy consumption
- Cleaner, cheaper, and healthier forms of mobility

In line with the European Green Deal objectives, the "Clean Energy for all European package", adopted in 2019, defines more ambitious targets, fixed at the EU level, under the existing binding EU target of at least 40% less GHG emissions by 2030 compared to 1990 levels:

- At least 32.5% energy efficiency improvement by 2030
- At least 32% consumption of renewable energy by 2030

The new energy rulebook establishes a new governance scheme: each member state is responsible for determining their contribution to the EU´s objectives by elaborating a National Energy and Climate Plan (NECP) for the next decade (2021-2030) and a long-term strategy for a minimum of next 30 years. These draft plans will be assessed by the European Commission to guarantee that the EU, acting together, can achieve its Paris Agreement commitments.

The European Green Deal ambition was reflected in the actions taken by the European Investment Bank (EIB). In November 2019, the Board of Directors of the EIB decided to elevate its level of commitment to climate and the environment by shifting the EIB from "an EU bank supporting the climate" into "the EU climate bank". This decision has relevant implications, such as the EIB's cessation of support for traditional fossil fuel energy projects. As a result, the EIB has become the first international financial institution to discontinue funding for fossil fuel projects and support only those fully aligned projects with the Paris Agreement.[15]

A recent green energy transition framework was adopted in July 2020, with the EU strategies for the integration of energy systems and hydrogen, whose main pillars are:

- Promote larger direct electrification in final demand
- Prioritize energy efficiency with a circular energy system
- Where electrification may be challenging, advocate for the use of clean fuels, such as renewable hydrogen and sustainable biofuels, and biogas

More particularly, the EU hydrogen strategy aims not only for sectors where electrification is challenging but also to ensure storage to balance the interminable flows of

[15] See EIB energy lending policy adopted on November 14, 2019.
Available at https://www.eib.org/attachments/strategies/eib_energy_lending_policy_en.pdf

renewable energy. Initially, the priority consists of producing renewable hydrogen using solar and wind energy, but later will be required other forms of low-carbon hydrogen in different stages:

- Between 2020 to 2024, the objective is to install in the EU a minimum of 6 gigawatts of renewable hydrogen electrolysers, resulting in the production of up to 1 million tons of renewable hydrogen.
- Between 2025 to 2030, the goal is to integrate hydrogen into the EU energy system, achieving at least 40 gigawatts of renewable hydrogen electrolysers and producing up to 10 million tonnes of renewable hydrogen.
- Between 2030 to 2050, the focus will be on maturing renewable hydrogen technologies and implementing them across all hard-to-abate sectors at a large scale.

Another significant step taken by the EU in November 2020 in response to the effects of the COVID-19 pandemic and in the context of recovery led to the green and the digital transition is the approval of unprecedented resources under the EU Recovery Plan ("Next Generation EU"), of which at least 37% will contribute to the green transition, and the long-term EU budget for 2021-2027 (the “Multiannual Financial Framework”- MFF), with specific allocations to fund climate action for at least 30%.

At current 2020 prices, this economic stimulus package is valued at EUR 2.018 trillion (or EUR 1.8 trillion at 2018 prices). It comprises the EU's long-term budget for 2021-2027 amounting to EUR 1.211 trillion (or EUR 1.074 trillion in 2018 prices), which is supplemented by an additional EUR 806.9 billion (or EUR 750 billion in 2018 prices) through the Next Generation EU Plan.

More recently, in July 2021, as part of the package to deliver on the European Green Deal, the EU Commission adopted a set of proposals to ensure a fair, competitive, and green transition to 2030 and beyond. More specifically, it set out a more ambitious proposal for reducing net GHG emissions by at least 55% by 2030, compared to 1990 levels (“Fit-for-55 package”), with a complete package that is expected to be approved in 2023-24.

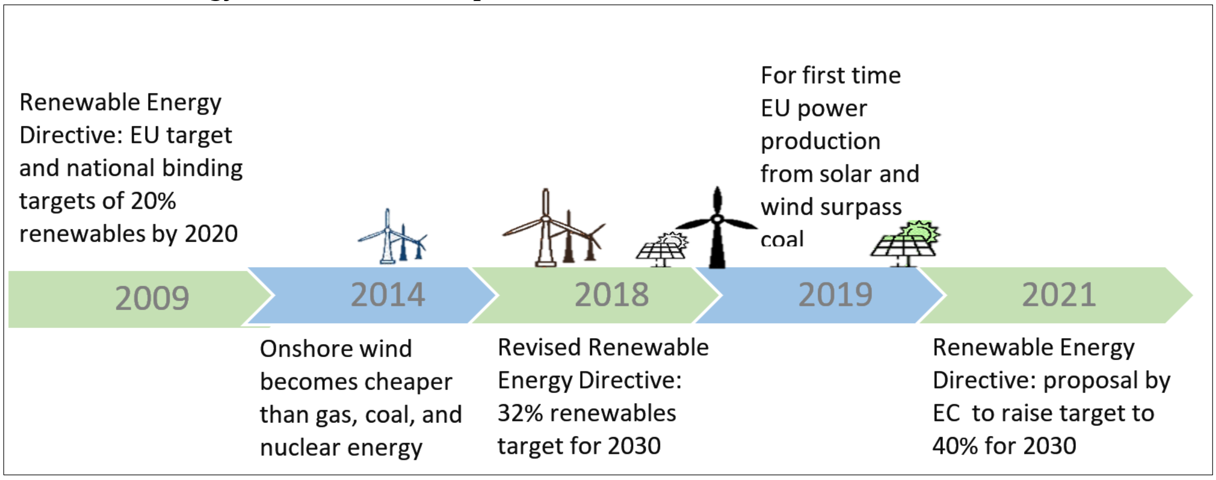
The Fit-for-55 package is an ambitious plan that revises and updates legislation for reaching the EU's climate objectives. This plan guarantees a socially just and equitable transition, while also supporting and reinforcing the innovation and competitiveness of EU industries. Additionally, it ensures a level playing field concerning third countries. Overall, it aims to support the EU's leadership position in the worldwide effort to combat climate change.

Among the most relevant legislative initiatives is the first Climate Law for the EU. Once adopted by both the European Parliament in April 2021 and the Council in June 2021, the EU incorporates into legislation the 2050 climate neutrality objective. The law establishes a mandatory EU climate objective to reduce by at least 55% the net GHG emissions (emissions following the deduction of removals) by 2030 in comparison to 1990 levels.

Another relevant legislative measure in line with the EU Climate Law is the review of the Renewable Energy Directive (RED Directive EU 2018/2001 of the European Parliament and of the Council). The legal framework for implementing renewable energy in all sectors has been evolving through this Directive, with varying targets being established over time, as depicted in Figure 3-8. In July 2021, the Commission recommended a revision to introduce some of the concepts included in the EU strategies for integrating the energy systems and hydrogen, adopted in July 2020, into EU law. This involves increasing the current EU-level goal of attaining at least 32% of renewable energy sources in the total energy mix to a minimum of 40% by 2030 and strengthening measures for transport, heating and cooling.

Figure 3-8

Renewable Energy Directive roadmap



Source: Renewable Energy Directive

As a matter of reference, under the Fit-for-55 package and the European Green Deal framework, the EU Commission has also proposed an ambitious legislative package:

- The review of the Energy Efficiency Directive, to increase the current energy efficiency target at the EU level from 32.5% to 36% for final consumption and to 39% for primary energy consumption.
- To prevent the EU's emissions reduction efforts from being undermined by increased emissions outside its borders through the relocation of production to non-EU countries or increased imports of carbon-intensive products, a Carbon Border Adjustment Mechanism will be implemented in full compliance with international trade rules.
- The review of the Energy Taxation Directive to bring the taxation of energy products and electricity in line with EU energy and climate policies. The objective is to promote the adoption of clean technologies and eliminate exemptions, as well as rates that currently incentivise the use of fossil fuels.
- To strengthen and expand the ETS, take additional measures including its extension to the maritime sector, and the creation of a second ETS for fuels for building heating and road transport.

- Establish a Social Climate Fund with a budget of €72.2 billion to provide temporary income support to vulnerable households and to finance energy efficiency investments to address concerns about increased energy costs to households and consumers.

More recently, although beyond the time frame of our research, we cannot ignore the global disruption in the energy market caused by Russia's invasion of Ukraine. In response, the European Commission introduced the REPowerEU Plan in May 2022, which aims to reduce the reliance on Russian fossil fuels, accelerate the transition to green energy and increase the resilience of the energy system across the EU.

(b) The USA policy and regulatory framework

The United States in recent history has occupied varying positions on how to address climate change. An example of that is the adoption of the Paris Agreement in 2015. On one hand, under President Obama, the USA was a party to the agreement when it entered into force in 2016, despite it not being submitted to the Senate for advice and consent. Later, President Trump announced the USA's withdrawal in June 2017, which became effective in November 2020. Presently, under President Biden, the USA again became a party on February 19, 2021.

While one of the distinct powers of the Senate is to approve international treaties, Congress is responsible for authorising laws to address the climate challenge and appropriating funding for relevant programs.[16] The federal government implements existing laws through regulation and programs and rulemaking by the U.S. Environmental Protection Agency (EPA).

Nevertheless, the environmental policy in the US is a joint responsibility shared by both the federal government and the individual states. Typically, Congress passes laws while the EPA develops regulations for federal environmental policies. However, state governments are

[16] The US Congress is the legislative branch of the federal government, composed of two chambers: the House of Representatives and the Senate.

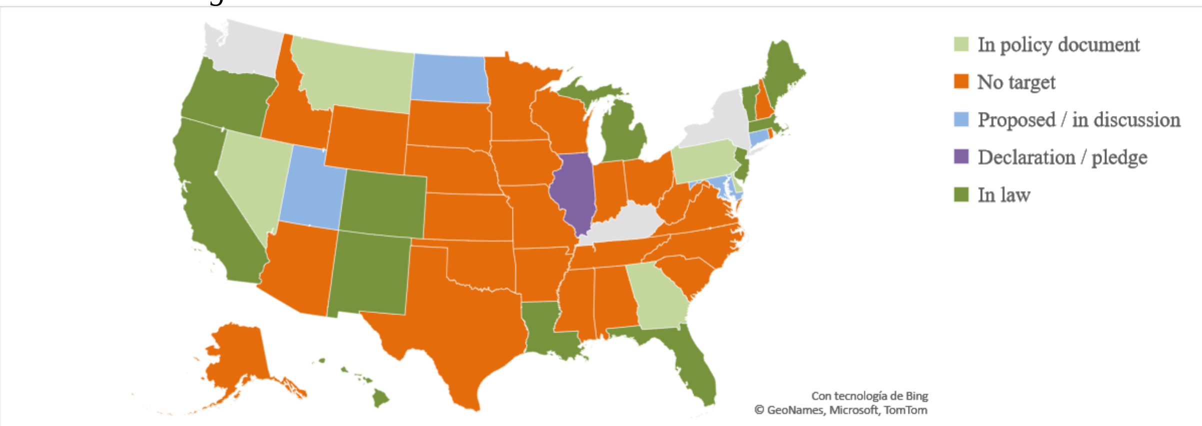
primarily responsible for enforcing these laws and there is significant variation in enforcement practices among the states. Additionally, some states go beyond the EPA requirements and impose additional environmental restrictions (Seltzer et al., 2022).

Due to the lack of comprehensive federal regulations on GHG emissions, state and local governments have implemented various measures. This was particularly evident when President Trump announced the US withdrawal from the Paris Agreement in June 2017. At that time, the U.S. Climate Alliance, comprised of governors from 24 states and Puerto Rico, pledged to reduce net GHG emissions in their states to a minimum of 50%-52% below 2005 levels by 2030 and to achieve net zero GHG emissions by 2050 at the latest.

Now, when we recollect the degree of commitment from the different states (see Figure 3-9), we realise that only 14 states, among them California, Colorado, Florida, Massachusetts, New Mexico, New York, and Washington, have ratified their net zero commitments in the form of law.

Figure 3-9

USA net zero regional commitments



Source: Net Zero Tracker. Data downloaded as of June 2022[17]

Historically, Members of Congress have expressed varying views on climate change, and proposals for legislative action have included several approaches[18], such as:

[17] Database available at https://zerotracker.net/analysis

[18] See Congressional Research Service. (2021, October 28). *U.S. Climate Change Policy*. https://crsreports.congress.gov/product/pdf/R/R46947

- tax policies and funding to support GHG-abating technologies
- carbon pricing to address most of the GHG emissions
- sectorial focus, including a standard for clean energy
- adaptation to climate change
- cooperation with third countries

In the context of our research, Congress has achieved various major milestones on climate and energy transition.[19]

The Clean Energy Standard Act was introduced in 2012 by Sen. Jeff Bingaman which aimed to implement a tradeable energy standard to decrease power sector emissions after Congress failed to act on climate regulation. After over two decades of routinely extending the tax credits for wind power production and investment tax credits for solar power, Congress reached an agreement in 2015 to extend and phasedown renewable energy tax credits. These tax credits have played a crucial role in making renewable energy competitive in costs, particularly in the absence of federal regulations.

In 2016 Reps. Carlos Curbelo and Ted Deutch formed the Climate Solutions Caucus, a bipartisan initiative in the House of Representatives. The Caucus was established with the aim of educating members to reduce climate risk with options economically viable and ensure safety in the country.

In February 2018 Congress passed a two-year budget deal that included crucial financial incentives consisting of tax credits and carbon pricing for investments in various advanced low-carbon technologies. This was noteworthy as it marked the first time in nearly eight years that there were Republican and bipartisan proposals led on carbon pricing.

[19] See a description of climate and energy policies developed by the US Congress by the Center for Climate and Energy Solutions, available at https://www.c2es.org/content/congress-climate-history/

Since Democrats regained control of the House of Representatives in 2019, climate change become a priority. Some of the most relevant initiatives included:

- A Green New Deal resolution in the House of Representatives and the Senate
- Additional market-based climate measures, including carbon taxes and standards for clean energy
- A Climate Solutions Caucus on a bipartisan basis in the Senate
- A Select Committee on the Climate Crisis in the House of Representatives to produce policy advice to address climate change.

The most relevant recommendations addressed by the Committee in the Climate Crisis Action Plan included:

  - Achieving net zero CO_2 emissions before 2050
  - Reducing net US GHG emissions by 37% in 2030 and 88% in 2050 below 2010 levels, while 12% of emissions remaining from the hard-to-decarbonise sectors
  - Producing health benefits by reducing pollution
  - Delivering climate and health benefits for USD 8 trillion (real 2018) by 2050

In December 2020, Congress approved an omnibus bill including the first major energy policy since 2007. There was a wide-ranging bipartisan package that encompassed clean energy technology research, development, and deployment along with tax incentives to support clean energy adoption. Furthermore, the legislation instructed the EPA to reduce gradually the consumption and production of hydrofluorocarbons (HFCs) over a 15-year period.

Within the Biden-Harris Administration, one of their immediate declared priorities is to take action to tackle the climate crisis.[20]

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[20] See The White House. (2021, September 20). *Priorities*. https://www.whitehouse.gov/priorities/

To contextualise these aims, President Biden´s comments prior to signing the January 27th, 2021 Executive Order "Tackling the Climate Crisis at Home and Abroad" were notable.[21] The order established a National Climate Task Force, a ground-breaking initiative comprising over 25 Cabinet-level leaders from various agencies collaborating to achieve ambitious objectives:

- Decrease GHG emissions by 50-52% below 2005 levels in 2030
- Reach net zero emissions by 2050
- Achieve 100% carbon-free electricity by 2035
- Allocate to disadvantaged communities 40% of the profits obtained from federal investments in climate and clean energy

As part of this Executive Order, there was a call for the preparation of a Climate Finance Plan, which was established on April 22nd, 2021. This was the first initiative of its kind within the US government, designed to provide financial resources that aid developing nations in lessening and/or preventing GHG emissions, as well as adapting to climate change effects.

With the Executive Order on Climate-Related Financial Risk of May 20th, 2021, the US government began to take action on another set of concerns about the implications of climate risk, such as disclosure of climate-related financial risks, their assessment by financial regulators or the resilience of pensions and life savings.

More recently, the Inflation Reduction Act of 2022, passed by Congress and signed into federal law by President Joe Biden on August 16, 2022, is relevant to our discussion despite falling outside the scope of our research, and we cannot disregard it. The law aims to fight against inflation through the reduction of the deficit and investment in domestic energy

[21] See The White House. (2021, January 27). *Remarks by President Biden Before Signing Executive Actions on Tackling Climate Change, Creating Jobs, and Restoring Scientific Integrity*. https://www.whitehouse.gov/briefing-room/speeches-remarks/2021/01/27/remarks-by-president-biden-before-signing-executive-actions-on-tackling-climate-change-creating-jobs-and-restoring-scientific-integrity/

production, and what is remarkable, building over a clean energy economy. One significant target consists of reducing GHG emissions by roughly 1 Gigaton by 2030, which would have an impact on climate 10 times greater than any other individual piece of legislation ever implemented.

In the context of increasing transparency on climate-related information disclosure, the U.S. Securities and Exchange Commission (SEC) launched a consultation on March 21st, 2022 on its draft climate disclosure rules for USA-listed companies. The rules were expected to be finalised by the end of 2022 and, if adopted in 2023, they will apply to most public companies beginning in 2024 in their 2023 annual reports.[22]

In response to investor demands that such information is pertinent to a company's financial performance and investment decisions, the SEC suggests that regular filings should include Scope 3 emissions, as well as direct emissions accounted for by Scope 1 and indirect emissions encompassed by Scope 2.

(c) Financial system regulation on climate and transition-related risks

Since the One Planet Summit took place in Paris in December 2017, central banks have increased their focus related to climate change, part of which was the establishment of the Network for Greening the Financial System (NGFS), an elective alliance comprising central banks and supervisory bodies.

Their declared aim is to assist in analysing and managing the financial sector's environmental and climate-related risks, as well as activate finance to facilitate the transition to a sustainable economy. As of the end of 2021, the NGFS consists of 105 members and 16 observers that cover the supervision of 100% of the globally systematically important banks, 80% of the internationally active insurance groups, and over 85% of global GHG emissions.

[22] See proposed rules for consultation at https://www.sec.gov/rules/proposed/2022/33-11042.pdf

Its first paper NGFS (2018), published in October 2018, highlights that climate-related risks are a source of financial risk, and central banks and supervisory bodies must ensure financial systems can withstand them. They also suggest that new analytical and supervisory approaches are necessary, including forward-looking scenario analysis and stress testing. The paper notes that although the tools and methodologies are in their early stages, central banks and financial institutions are beginning to understand these risks and the need for a better approach.

In April 2019, the NGFS published six, non-binding recommendations (NGFS, 2019), to encourage a greener financial system. The first four target central banks and supervisors, and financial institutions to integrate climate-related risks to monitor financial stability, incorporate sustainability factors into their portfolios, close data gaps, and build awareness and capacity through knowledge-sharing and technical assistance. The last two recommendations aimed at policymakers to attain coherent and sound information on the environment and climate, and to support the development of an economic activity taxonomy.

US regulatory financial bodies are taking steps towards implementing similar recommendations as those suggested by the NGFS:

(a) The Office of the Controller of the Currency (OCC) the independent body of the US Department of the Treasury, which oversees national banks and federal savings branches is developing a set of management principles for climate risk.

(b) The Federal Deposit Insurance Corporation (FDIC) launched a consultation on 30th March 2022 on draft principles for climate risk management by large financial institutions with total consolidated assets over $100 billion. The principles under consultation are similar to those proposed by the OCC.

(c) The US Federal Reserve is in the early development phase regarding climate stress tests and climate scenario analysis for banks, with no specific timeline defined for launching a tailored climate stress test for banks or integrating climate risks in banks' stress tests.

The significance of financial regulation on climate-related matters in Europe is exemplified by the establishment of an internal climate change centre by the European Central Bank (ECB) in January 2021, reporting directly to the President. The centre is responsible for defining the ECB's climate agenda and coordinating climate change and sustainable finance issues across the organization. The goal of the centre is to ensure that the ECB integrates climate considerations into its decision-making processes and contributes to the transition to a low-carbon economy.

In July 2021, the ECB announced an action plan to include climate change considerations in several areas:[23]

(a) Incorporating climate change risks and policies into macro models and projections

(b) Analysing the impact of climate change on monetary policy

(c) Implementing Sustainable Responsible Investment in its portfolio and pension fund

(d) Preparing top-down climate stress tests and assessing physical and transition risks from the financial stability perspective

In the area of banking supervision, the Single Supervisory Mechanism (SSM) comprises the ECB and the EU national supervisory bodies. Their recent activities include climate risks in their risk maps and supervisory for those relevant institutions that describe how climate and environmental risks are expected to be integrated. One of their supervisory priorities for the

[23] The ECB presented an action plan to include climate change considerations in its monetary policy strategy, available at https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210708_1~f104919225.en.html

period 2022-2024 is addressing identified vulnerabilities in banks as a result of their exposure to climate-related and environmental risks.[24]

iii. Preliminary transition risk assessment of the energy sector

The transition to a more decarbonised economy will involve significant changes in capital allocation and financial flows for almost all sectors, and specifically to the focus of our research, the energy sector and oil and gas companies.

At the same time, some of the required technologies to reach the NZE are still under development, representing a great opportunity to incentivise those that do not yet have sufficient acceptance by society or those whose low competitiveness makes them insufficiently profitable, by allowing companies to accelerate the net reduction of their GHG emissions.

Therefore, the financing of the energy transition will be a challenge and an opportunity because of the significant reallocation of financial resources that must be able to align the interests of society, companies, and their stakeholders.

Companies in the oil and gas sector are starting to define different capital reallocation strategies to thrive in the energy transition and are challenged to convince their investors and financial institutions that this is a credible and, above all, profitable process. In this process, we find companies that are progressively transforming to become multi-energy suppliers through different technologies:

(a) matured renewable energy sources such as wind, solar or hydraulic

(b) some not yet accepted or competitive enough, that can play a decisive role in accelerating the achievement of the objectives of the energy transition. Such is the case of the manufacture of biofuels, the production of blue and green hydrogen, petrochemicals applied to

[24] The SSM stablishes annual supervisory priorities for the three following years, available at https://www.bankingsupervision.europa.eu/banking/priorities/html/ssm.supervisory_priorities2022~0f890c6b70.en.html

synthetic fuels, and CO_2 capture, storage, and subsequent use (CCUs) into clean energies, to name but a few.

In turn, since many of these technologies, matured or not, are interconnected, companies in this sector could obtain significant synergies and generate a virtuous circle.

From the practitioner's perspective, a significant shift in the purpose of the corporations occurred on August 19th, 2019, when the American Business Roundtable issued a statement titled "Statement on the Purpose of a Corporation". They stated that the first objective of their companies should not be the creation of value exclusively for its shareholders, but to seek it for all its stakeholders, such as employees, suppliers, customers, and other groups, including the communities where they operate: "Each of our stakeholders is essential. We commit to deliver value to all of them, for the future success of our companies, our communities, and our country" (p.1).[25]

But what makes this publication different from other similar manifestations in the social responsibility reports of various listed companies is the great impact of the statement being signed by 181 CEOs, representing 30% of the total U.S. market capitalisation, from Apple to Walmart. In a country where the traditional purpose of its corporations lies in "shareholder capitalism", it is beginning to become "interest group capitalism" or "social capitalism".

Under those statements, we can read that companies are no longer intended solely to create value for their shareholders but also to have the social license to carry out their activities and meet the needs of all their stakeholders. For their part, some investors and institutions that channel financial flows may exclude the financing of fossil energy, as they do not have as their sole reference the requirement for profitability adjusted to the risk of their investment, but also

[25] See Business Roundtable Statement on the Purpose of a Corporation, available at https://opportunity.businessroundtable.org/ourcommitment/

to meet sustainable objectives and adjust their investment policies towards companies that meet appropriate environmental, social engagement and governance (ESG) criteria.

At this point, we may be wondering whether these clean energy technologies have reached sufficient momentum for fossil energy companies to garner the support of policymakers, investors, and financial institutions, as well as the acceptance of society. Some power utility companies began earlier to change their fossil fuels energy mix towards cleaner energies. If we compare them with the oil and gas companies, can we observe a shift in investor preference that is reflected in their market value? Moreover, how should we reinterpret the new business risk and profitability of oil and gas companies that may decide to transform themselves into multi-energy suppliers through these cleaner technologies? Are the financial markets willing to increase the channelling of financial resources to companies in the oil and gas sector to address these clean investments?

To start answering these questions, we have selected two groups of the most relevant energy companies in their respective marketplaces in the USA and Europe: on one hand, oil and gas companies (Exxon, Eni, BP, Total, and Repsol), and on the other, power utility companies (NextEra, Enel, Orsted, Electricité de France, and Iberdrola), from the end of December 2013 (in the case of UK-Denmark since June 2016, starting with Orsted listing) to the end of May 2022.

Given that all have different sizes and publish different sectorial emissions calculations, we have normalised them by a relevant measure of their activity, as proposed in Chapter 4 Data section:

Emissions intensity = Emissions / Activity

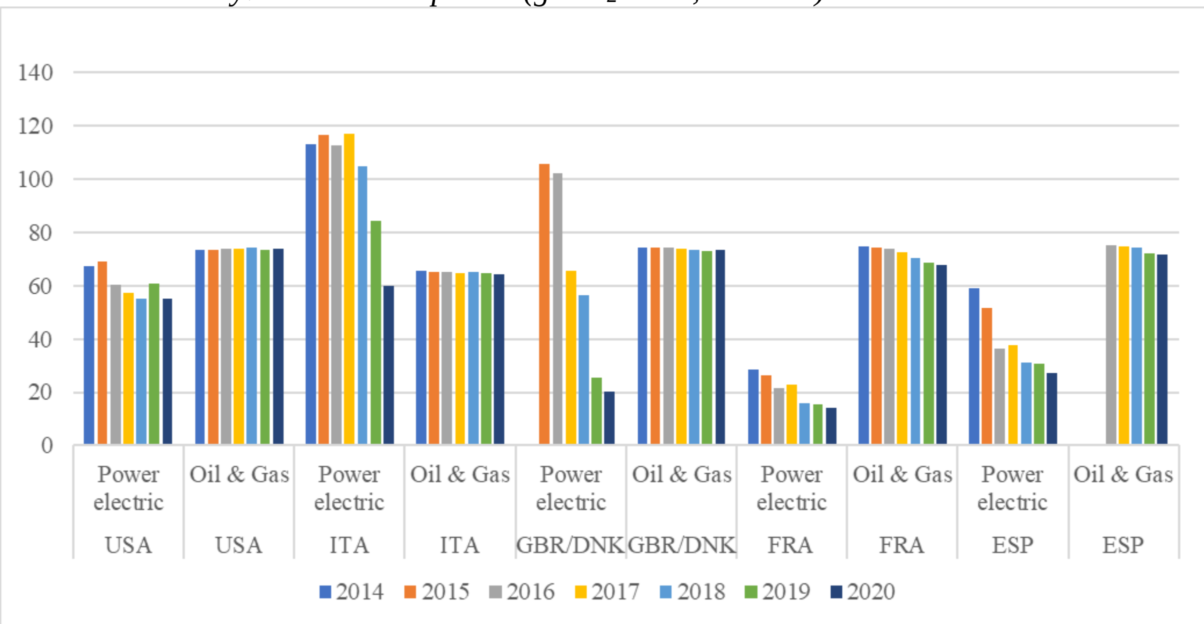
where the emissions intensity is measured in relation to the energy produced in megajoules.

The evolution of the emissions intensity derived from the selected companies is provided in Figure 3-10 and we can observe that the selected power utility companies began their energy transition to cleaner energy sources earlier and at a higher speed when comparing their lower carbon intensity in relation to their respective country selected oil and gas companies; the only exception is the case of Italy, where the speed of reduction started later in 2018.

This evolution is consistent with Bernardini et al. (2021)'s results about European power utility companies which, in their analysed period 2006-2016, reveal a change in their energy mix, in particular for companies with higher carbon emissions.

Figure 3-10

Emissions intensity: Selected companies (grCO$_2$-e/MJ, 2014-20)



Source: Own calculations. Data downloaded from Transition Pathway Initiative database[26]

[26] Database available at https://www.transitionpathwayinitiative.org/sectors

The evolution of their respective market capitalisation, with data sourced from Bloomberg, is described in Figures 3-11, 3-12, 3-13, 3-14, and 3-15, showing that the selected power utility companies have surpassed oil and gas companies in all cases, except in France (see Figure 3-14).

Figure 3-11.
Market cap evolution: Exxon vs. NextEra

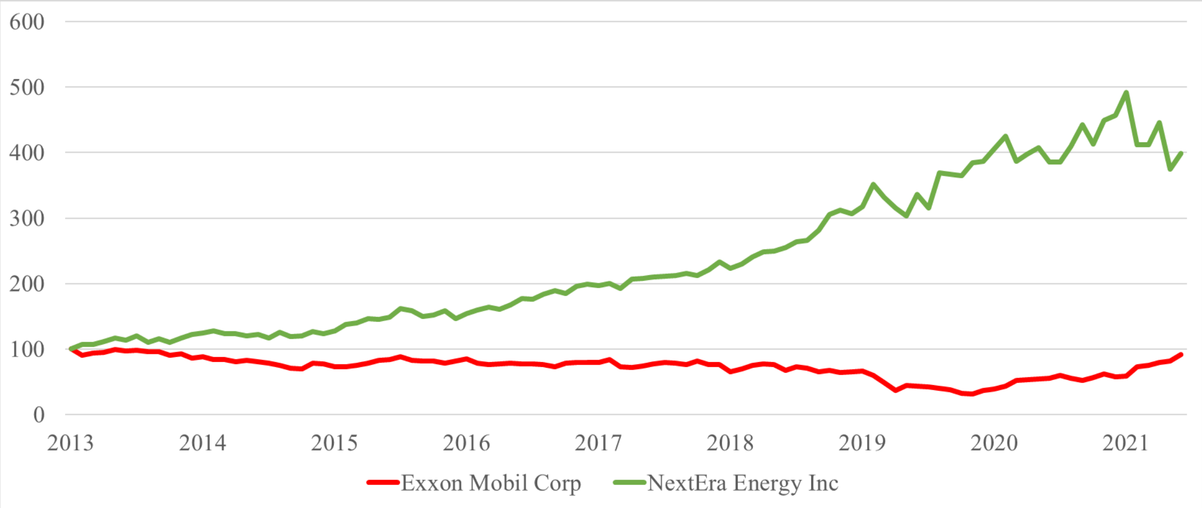


Figure 3-12
Market cap evolution: Eni vs. Enel

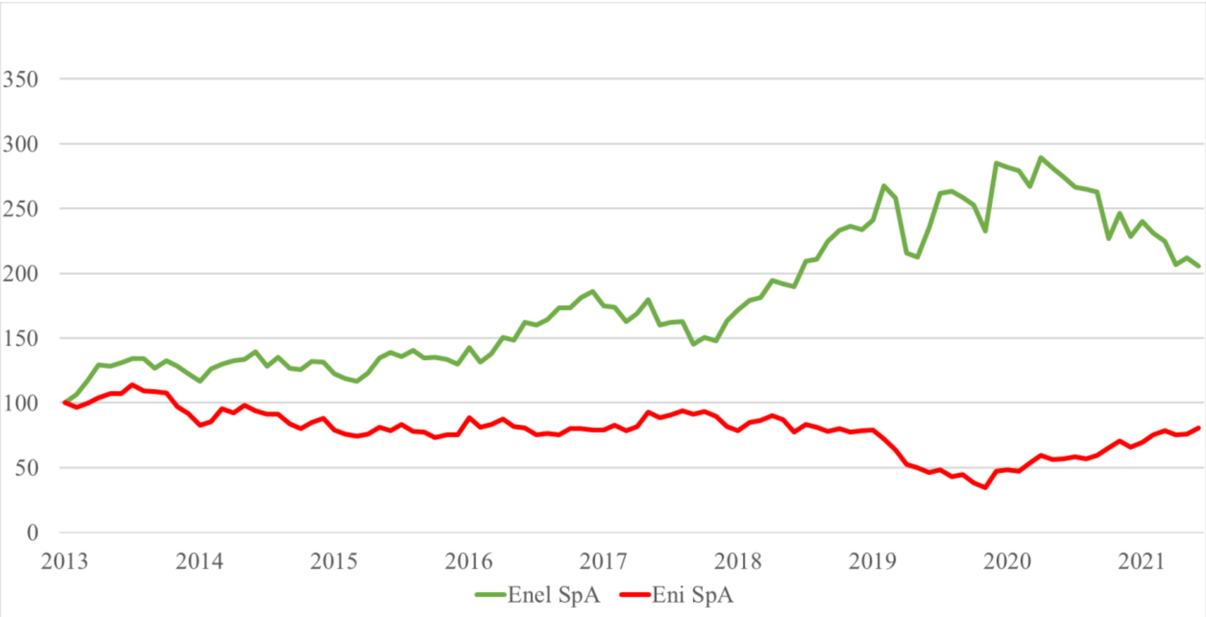


Figure 3-13

Market cap evolution: BP vs. Orsted

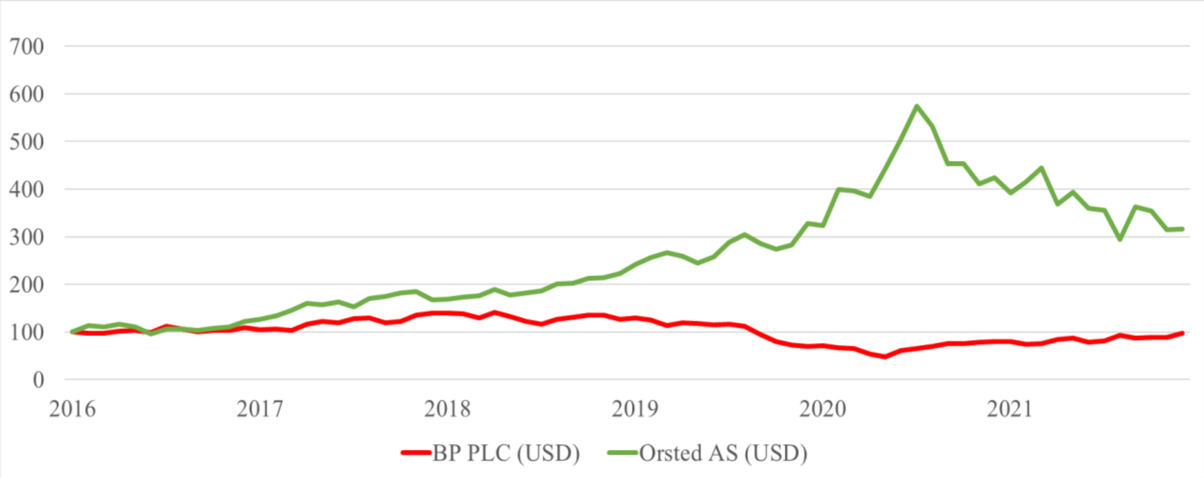


Figure 3-14

Market cap evolution: Total vs.EDF

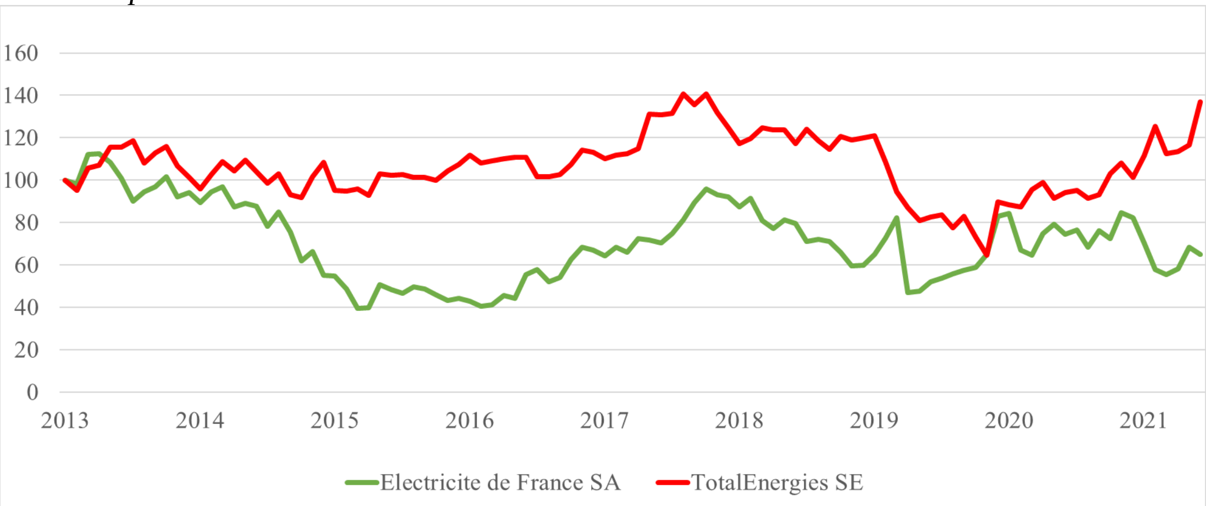
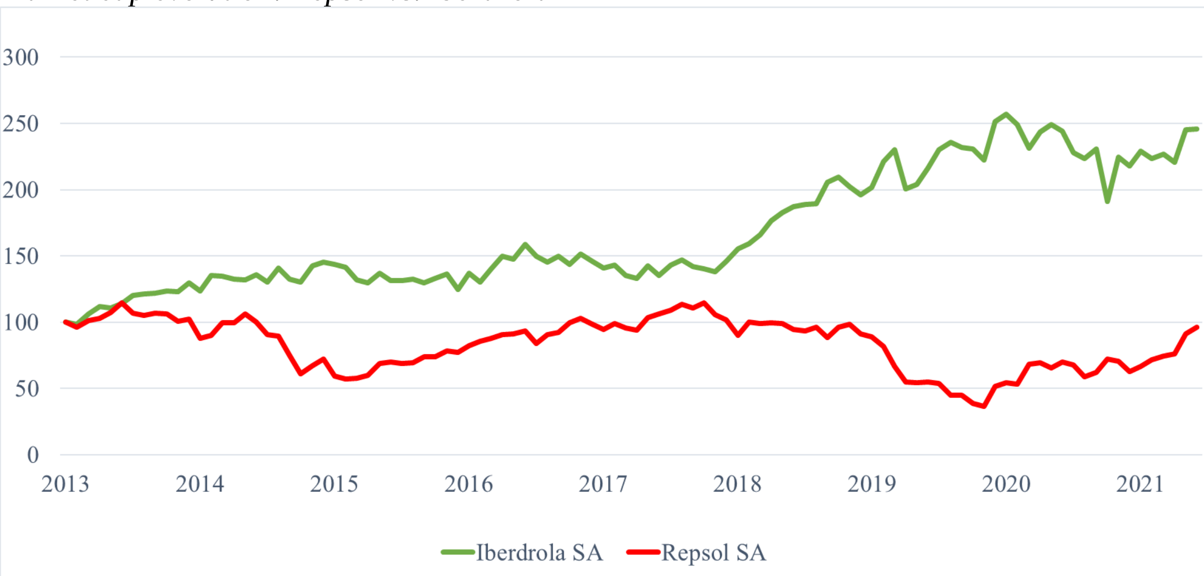


Figure 3-15

Market cap evolution: Repsol vs. Iberdrola



A remarkable result is the case of NextEra Energy Inc., which is a Florida-based company, and the world’s biggest investor-owned producer of solar and wind energy; it surpassed in market cap Exxon Mobil Corp, the world's largest private-owned listed oil and gas company (see Figure 3-11). The same can apply to the other European power electricity companies, which are now worth more than their comparable oil and gas companies, underlying investors' interest in the cleaner energy companies, except for Total Energies in France (see Figure 3-14).

Our research considers a broader sample of companies in these sectors, and we aim to understand whether there is an excess return because of a change in investors´ risk assessment regarding the energy transition, which progressively incorporates initiatives to direct their investments into less fossil fuel-intensive sectors. We also aim to shed some light on the degree to which investors are pricing the energy transition risk (also known as “carbon transition risk” or the other side of the coin, a “green factor”) in the stock returns of oil and gas companies. This will be accomplished by comparing the stock portfolio of oil and gas companies with that of cleaner energy producers.

4 DATA PROCESS AND SOURCES

4.1 Context about data collection

As described in the literature review section, there are several studies covering aggregated data or global economic sectors in an attempt to measure the pricing of carbon risk by focusing on the way in which stock returns reflect investor concerns regarding carbon risk.

Nevertheless, to the best of our knowledge, our research on transition risk in the energy sector and oil and gas companies will be a novel approach, and therefore we do not have a specific academic reference as to how to compile the data section. For this reason, we will follow an integrated approach, and thereafter we will elaborate on our contribution.

Almost all academic literature uses the set of data based on global carbon emission levels, the percentage changes in emissions, or a carbon intensity index defined as a percentage of emissions to revenues to avoid autocorrelation constraints with companies' sizes and to make homogeneous comparisons.

The academic literature also commonly refers to the use of qualitative data obtained from Environment, Social and Governance (ESG) scores or ratings, particularly focusing on the environmental aspects, such as the public perception score or preparedness score to measure the level of commitment to managing environmental risks and adaptability to new environmental technologies.

The market approach to guiding investors toward climate-conscious investments typically involves tools such as index weightings, rankings, or allocations based on climate-related risks. These tools tend to show investors qualitative and quantitative data, often based on a company's carbon footprint, to evaluate its climate risk. Carbon emissions are commonly used as a proxy for this metric.

Nevertheless, methodologies, scope, and coverage of reports and qualifications vary greatly between providers of scores, ratings, and market indexes.

In this respect, recent academic research (Avramov et al., 2022) has been focused on the divergencies in ESG ratings and their impact on sustainable investing decisions. The study finds inconsistencies in ESG information disclosure and ratings from various rating agencies, leading to less engagement by investors in corporate ESG issues. The results suggest a cautious evaluation of rating uncertainty and highlight the need for policymakers to establish a clear ESG performance taxonomy and standardized sustainability reporting to improve ESG investment and engagement.

In this context, in January 2021 the European Securities Markets Authority (ESMA), the securities markets regulator in the EU, called for legislative action on ESG ratings and assessment tools on the European Commission to ensure their quality and reliability.[27]

With all of these elements in mind, and to analyse whether there is any carbon transition risk in oil and gas companies, we will construct our own quantitative data set that makes them comparable with cleaner energy producers:

a) where emissions are placed in their value chain
b) how efficiently the energy is produced and therefore how to establish a carbon emissions indicator based on their activity, and
c) how they compare with companies involved only in renewable energy generation, i.e. without any carbon footprint.

We will start by describing the analytical steps we have followed to complete the process of data collection to facilitate the reading, based on the academic literature described previously as well as market practice:

[27] The detailed ESMA call for legislative action is available at: https://www.esma.europa.eu/document/esma-letter-ec-esg-ratings

a) Define the scope and boundaries of oil and gas companies and cleaner energy producers

b) Determine the corporate geography and investors' ownership

c) Define the proxy that may describe the carbon transition risk

d) Identify the time series that may better capture the market assessment

e) Select the databases to perform the research.

4.2 Analytical process to collect the data

i. The scope and boundaries of oil and gas companies and cleaner energy producers

To define the scope and boundaries of GHG emissions in oil and gas companies we will follow the evolving boundaries description of the Science-based Target initiative (SBTi). The SBTi, which is a collaboration between the Carbon Disclosure Project (CDP), the United Nations Global Compact, World Resources Institute (WRI), and the World-Wide Fund for Nature (WWF), guides on developing setting science-based targets for companies operating in oil, gas, and integrated energy.

As defined in their guidance (SBTi, 2020), the sector comprises oil and gas (O&G) companies, as well as energy companies that engage in oil and gas activities. However, since these companies are no longer exclusively focused on oil and gas, they can be viewed as entities that are undergoing a transition.

Oil and gas energy companies vary widely in their core activities, and for clarification purposes, SBTi follows the classification of IPIECA, the global oil and gas association, founded at the request of the United Nations Environment Programme in 1974.

According to IPIECA (2021), the O&G industry is generally categorised into three primary business lines according to their activities:

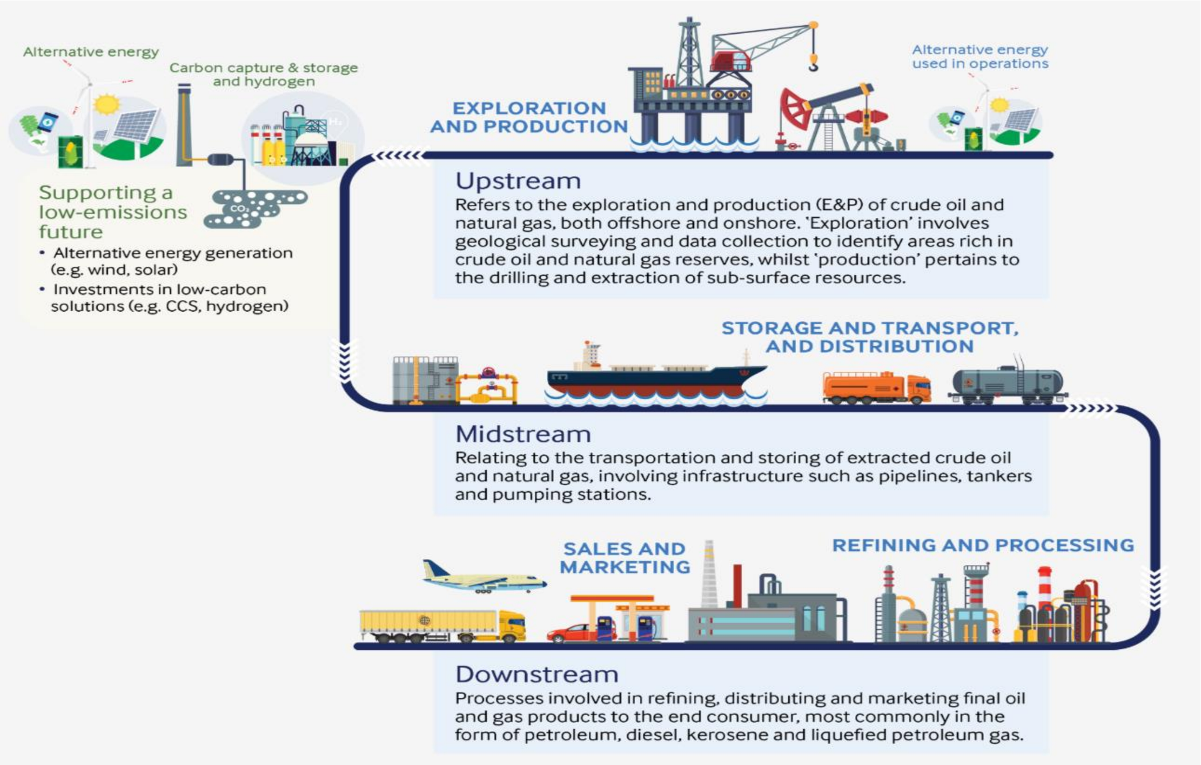
a. Upstream, which includes exploration, drilling, production and field services.

b. Midstream, comprises pipelines, terminals, maritime transport and storage services.

c. Downstream, which includes refineries, retail stations, petrochemicals and natural gas distribution.

It is worth mentioning for the purposes of our research that the IPIECA (2021) roadmap, as described in Figure 4-1, recognises the fact that the sector has started to focus on renewable energy and low-carbon solutions, as a preparation for their energy transition, in addition to the traditional business segments.

Figure 4-1:
Oil and gas sector: roadmap of business segments



Source: IPIECA (2021)

On the other hand, SBTi does not consider some activities in this value chain as they are not significant in terms of carbon emissions methodology, such as:

a. O&G services and logistics, since they do not have the decisions on the investments required to transform resources into reserves.

b. O&G transportation and storage, as pure players of midstream facilities, are responsible for a small percentage of overall emissions, only about 1% of the O&G sector, according to data from the Oil Climate Index.[28]

c. O&G trading is not considered a significant driving force for change in the sector.

The other area of interest to mention in this section is the scope for measuring carbon emissions. As defined above, oil, gas, and energy companies with oil and gas activities trade energy products at multiple points of their value chains. The methodology generally accepted to measure their carbon emissions is established by Greenhouse Gas Protocol, which furnishes the most extensively used GHG emissions accounting standards for companies. According to the Corporate Standard of this protocol, companies are obligated to report all Scope 1 and Scope 2 emissions. In contrast, Scope 3 is optional, as stipulated in the Corporate Value Chain Accounting and Reporting Standard.[29]

This methodology is designed to encompass the three categories of emissions:

- Scope 1 — This pertains to the direct emissions from the company´s operations. This includes emissions resulting from leaks of methane in the upstream activities, powering the engines to drill, or from vessels to transport the oil or gas.
- Scope 2 — This covers the indirect emissions that a company generates from the energy it consumes. For instance, this includes emissions from the generation of electricity procured from the grid to power auxiliary services, or from the production of hydrogen acquired from a third party to be processed in a refinery.

[28] Oil Climate Index (OCI) initiative is supported by the Carnegie Endowment for Peace think tank institution. The OCI estimates both the amount and the profile of greenhouse gas emissions produced throughout an individual oil's supply chain. For full estimates see https://oci.carnegieendowment.org/

[29] GreenHouse Gas Protocol methodology for Scope 3 available at https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard-EReader_041613_0.pdf

- Scope 3 — This involves all emissions not linked with the company itself, but for which it holds indirect responsibility across the value chain. An example of such emissions would be those that occur during the combustion of fuel by end users.

Amongst others, the methodology incorporated by SBTi in its evolving guidance is followed by the International Energy Agency (IEA) to establish its benchmarks and targets, and by Transition Pathway Initiative (TPI), a leading independent corporate climate institution that elaborates comparable reporting benchmarks. In our research on the oil and gas sector, we will adopt Scopes 1, 2, and 3, as used by the IEA and TPI, because they provide a more comprehensive view of emissions across the entire value chain of the sector.

Likewise, to establish the comparison with cleaner energy producers, we will start the analytical process with the power utility sector, and later turn our focus to the pure renewable energy generation sector which does not entail carbon emissions, and therefore requires a separate section.

For our analysis, we aim to evaluate the carbon emissions performance in the power utility sector solely arising from electricity generation. This approach aligns with the methodology laid out by the IEA and the TPI. Even though the most prominent power utility companies are also involved in the distribution or retailing of electricity produced by other entities or have considerable participation in other activities, such as gas distribution and retail, this approach covers almost all of the emissions from the power sector. Additionally, this methodology is consistent with the IEA's targeted benchmarks.

In both the oil and gas and power utility sectors mentioned earlier, emissions disclosures vary depending on the corporate boundary established with their affiliates. Two high-level approaches are commonly used: the equity-share approach and the control approach. For this purpose, we will follow the criteria adopted by TPI, which implies accepting the measure chosen by companies in their voluntary emissions reported, taking any of the above approaches to delimit their boundaries, as long as they are representative and consistent in reporting emissions and activity in the same boundary.

With this context in mind, in the following section, we will elaborate on the criteria that we will propose in our research to analyse companies of the oil and gas sector and cleaner energy producers, given the implications described above and the degree of ownership, control and regulation made by national governments and their public market listing.

ii. The investors' ownership and company headquarters' corporate geography

We decided to restrict our research to oil and gas companies and cleaner energy producers domiciled in two geographical areas (Europe and North America), and to privately owned companies, for reasons that will be described below.

The analysis starts with the oil and gas sector to extract subsequent conclusions when compared to the cleaner energy producers.

Firstly, to contextualise this section, it is important to classify the oil and gas sector consistently. According to IPIECA (2021) and the IEA (2020), oil and gas companies can be grouped into the following three main categories:

a) Corporations that are fully or mostly owned by national governments, such as national oil companies (NOCs) that focus on domestic production and international NOCs (INOCs) that have both domestic and significant international operations. This category is made based on upstream operations.

NOCs are typically the largest companies in terms of production and reserves. They are mandated by their home governments to develop national resources and have a legally defined role in upstream development. Although some NOCs may also operate downstream and even outside their home country, their primary asset base is usually in their home country's upstream sector.

INOCs share similarities with NOCs in terms of governance and ownership, but their upstream investments extend beyond their home country and often involve partnerships with host NOCs or private companies. They are major players in global oil and gas markets and typically sell their production internationally through their marketing subsidiaries or associated NOCs. In some exceptional cases, they may transport their production back to their home country if it is economically viable. INOCs also tend to dominate the refining sector in their home country.

b) The category of privately owned companies can be further classified into two groups. The first includes the "Majors", also known as international oil companies, (IOCs) or integrated energy companies (IECs). The second includes the "Independents" that are either independent upstream operators or fully integrated companies, like the Majors but smaller in size.

The "Majors" are integrated companies listed on the stock exchanges of the US and Europe. While their upstream division represents most of the financial value, in physical terms, these companies are mostly net buyers of oil for their refining operations, where throughputs typically exceed their crude production. The separation of their upstream production, marketing and supply to their refineries makes them significant players in the international oil market.

c) Also, there are three other company types, mainly privately owned:

- Service companies: These are specialist engineering services providers that oil and gas companies depend on for drilling, reservoir management, and infrastructure construction.
- Pure downstream companies: They operate refineries and retail networks.
- Trading companies: They engage in the physical trading of oil products and LNG and may also invest in assets related to transport, refining, distribution, and storage.

Secondly, to focus the analysis, we need to select or discharge certain categories of oil and gas companies in terms of whether they comply with the following criteria needed to cover the aims of our research:

- Reliable disclosure of information about carbon emissions and energy produced
- Listed in liquid stock exchanges, and therefore with access to market prices
- Relevance to assess comparable contribution in financial performance terms

When we analysed the segment of state-owned companies (NOCs and INOCs), we started with the collection of data from public sources that could validate the first two criteria described above. Concerning the availability of reliable information, Climate Accountability provides a methodology to sort the state-owned companies.[30]

Based on this study and our review, only a limited number of these companies are publicly listed on stock exchanges and therefore with limited disclosure and access to market prices. Following alphabetical order, this group comprises CNOOC (China), Ecopetrol (Colombia), Equinor (Norway), Gazprom (Russia), Oil and Natural Gas Corporation (ONGC, India), Petrobras (Brazil), PetroChina (China), PTT (Thailand), Rosneft (Russia), Saudi Aramco (Saudi Arabia), Sinopec Corp. (China), Sonangol (Angola), TAQA (United Arab Emirates), and YPF (Argentina).

Nevertheless, a factor that we believe is even more relevant for our research is that state-owned companies have a very different purpose and complexity in comparison to privately owned companies.

Although the impact of energy transition affects all oil and gas categories, it is important to examine the dependence of host countries on revenues coming from their state-owned companies and how these companies are managed. In our view, host states influence them, and the associated risks make state-owned companies' financial performance difficult to compare with privately owned companies.

[30] The Climate Accountability Institute is a non-profit research and educational organization focused on climate change and the contribution of fossil fuel producers. Full details are reflected in: https://climateaccountability.org/pdf/TrainingManual%20CAI%2030Sep19lores.pdf

The Natural Resource Governance Institute (NRGI) elaborates on this idea and explains that there are two mutually exclusive options: either the world takes necessary measures to limit global warming, or NOCs can profit from these investments.[31]

NGRI (2021) acknowledges that NOCs cannot be compared to IOCs; they are responsible for providing steady revenue streams to support governments, public employment, social services, and fulfilling various other roles. As the energy transition impacts the future of oil and gas, NOCs face significant risks to balance, and their flexibility to invest in costly projects will reduce while the opportunity costs rise.

This reflection is particularly relevant for those countries whose economies are developing or those in non-OCDE countries.

Our conclusion is that to enable comparable financial performance and seek insights into our research questions and business model's approach, we need to base our analysis on privately owned and listed companies, with only one state-owned company exception (Equinor, formerly Statoil), for its comparable contribution in financial performance terms. This company is based in Norway, a developed country without the financial constraints of non-developed economies and a country leading the climate change initiatives, a relevant aspect that we will elaborate on hereafter in the context of home-based country considerations for oil and gas companies.

Next, we need to focus and limit the scope to privately owned companies, and our conclusion is simpler. It is easier to discharge certain companies involved in the oil and gas companies value chain, as described previously when SBTi does not consider them sufficiently distinct or significant in terms of carbon emissions methodology such as:

a. O&G services and logistics

[31] NRGI is a non-profit organisation that provides policy advice and research, whose aim is that people and countries rich in oil, gas, and minerals achieve sustainable and inclusive development.

b. O&G pure midstream facilities players
c. O&G Trading

What this means is that we will focus on the following segments:

a. Majors (IOCs) or integrated energy companies (IECs)
b. Independents, either pure upstream operators or fully integrated companies, such as the Majors but smaller in size.
c. Pure downstream companies, operating refineries, and retail networks

To conclude this section, we will describe the arguments focusing on the relevance of the corporate geography of oil and gas companies.

For this purpose, we need to refer to the IEA (2020), which mentioned that “in recent years, rising global emissions have intensified scrutiny of the industry also on broader environmental grounds, especially in Europe and North America. This is also reflected in heightened engagement by investors in listed oil and gas companies on climate-related risks and restrictions in some areas on access to finance” (IEA, 2020, p.34).

In the academic literature, we can find several studies that analyse the factors determining climate change strategies in the oil and gas sector. According to Rowlands (2000), in a review of BP’s and ExxonMobil’s stances on climate change, company-specific characteristics are relevant, but he acknowledges that additional research is necessary to determine the relevance of management structures and the home countries of corporations.

Skodvin and Skjaerseth (2003) conducted further research to explore the sources of changes in the corporate climate strategies of major oil companies over time. They identified three potential reasons for these changes: internal factors within the companies, the political context of their home countries and changes in the international institutional context of the oil industry.

Their analysis demonstrated that differences in the domestic political context in the home country of the companies played a more significant role in explaining corporate climate strategy than company-specific factors. Despite being a global player, the oil and gas industry is closely tied to home-based countries where multinational companies have their roots, headquarters, and primary operations. Therefore, changes in the political context of their home country can have a significant impact on the companies' climate strategies. This argument also serves to explain the significant differences between the strategic responses of European-based and US-based oil and gas companies to climate change.

Taking into consideration the perspectives of both academics and practitioners standpoint, as well as the changing policy and regulatory landscape in Europe and North America, we believe that focusing on these geographical areas will provide valuable insight for addressing our research questions.

For these reasons, besides the privately owned listed companies, we will also include state-owned European companies, if any (Equinor is the only case), whereas in North America it is not the case for any state-owned company. This criterion is consistent with the fact that Norway is not as dependent on hydrocarbon revenues as other developing economies or non-OECD countries.

In summary, our analysis will be based on data collection from privately owned listed oil and gas companies based in Europe and North America, with only one state-owned company exception that is based in Europe (Equinor, formerly Statoil, based in Norway).

As a matter of consistency, the same will apply when we compare oil and gas companies with cleaner energy producers, analysing privately owned listed companies based in Europe and North America, including European state-owned companies if any. This way, cleaner energy producers will be classified from the totality of energy companies that have the lowest carbon emissions indicator, starting the analysis with power utility companies and thereafter in a separate analysis with renewable energy companies that have zero carbon emissions. We will elaborate on the list of cleaner energy producers based on these criteria and in conjunction with the emissions indicators and data sources section.

iii. The proxy to identify the carbon transition risk

In contrast with most of the academic literature available, our aim is not to identify and distinguish the sectors that may be involved in a carbon risk activity by a series of indicators. We can start by acknowledging without any doubt that the energy sector is involved in a carbon risk business and then we aim to construct a proxy for the transition risk.

To construct this proxy, we have selected a carbon emissions intensity as the indicator. The first step relates to the fact that oil and gas and power utility companies have different sizes and sectorial emissions calculations that must be normalised by a relevant measure of their activity:

Emissions intensity = Emissions / Activity

We have decided to select emissions intensity based on the activity component, in the same way companies report their public target commitments to reduce their emissions, reflect the energy efficiency component, and capture their shifts into low or zero-carbon energy in their value chain. For oil and gas companies, the emissions are measured concerning energy produced in megajoules, while power utility companies are measured in megawatts per hour.

To convert all of them to the same unit, we have translated power utility sector emissions initially measured in "metric tons of CO_2 equivalent per megawatt hour" to "grams of CO_2 equivalent per megajoule" using the conversion factor of $1x10^6$ divided by 3,600.

iv. The time series to measure the market assessment

Although climate change and its effects have been a subject of concern for a long time, authors such as Görgen et al. (2020) and Pástor et al. (2022) have focused on recent years, in the periods 2010-2017 and 2012-2020, respectively. Some of their arguments include the scarcity of data coverage for a longer period and the fact that carbon risk became relevant for financial markets only very recently.

In this line of arguments, we have also considered reducing our analysis to a shorter period, from January 2014 to December 2020 and up to December 2021, where data are available, for the following reasons:

a) Awareness of climate change

We could start our awareness journey as early as 1992, with the "Earth Summit" organised by the United Nations, where the United Nations Framework Convention on Climate Change (UNFCCC) was created as an initial measure to tackle the issue of climate change. Another significant milestone was in 1995 when nations initiated negotiations to enhance the worldwide response to climate change. Two years later, the Kyoto Protocol was ratified, which legally obligated developed country Parties to reduce their GHG emissions.

Nevertheless, the most recent and transcendental agreement took place in 2015, at the 21st Conference of the Parties in Paris. During this conference, specific targets were established to fight against climate change, accelerate action and increase investments towards achieving a sustainable low carbon future.

In our view, awareness of climate change risks has experienced a turning point since 2015 and has increased significantly in the following years, based on a couple of reflections:

i) The World Economic Forum´s annual Global Risks Reports have reflected the growing significance of climate risks. Since 2014, extreme weather, failure of climate action, and human-induced environmental damage have consistently ranked in the top five issues in terms of their impact (World Economic Forum, 2021 and 2022).

ii) The review of literature about climate-related risk and financial performance shows a significant surge in interest among researchers and practitioners during recent years. A research study carried out up to September 2021 by Atz et al. (2022) found 1,141 primary peer papers and 27 metareviews (which were based on approximately 1,400 underlying studies) published between 2015 and 2020. This amount of research is comparable to all papers published before 2015. It is a clear signal of a very recent change in relevance.

iii) The availability and transparency of carbon emissions data.

Although companies have been producing corporate and social responsibility reports since the 1990s, with further evolution in recent years towards sustainability reports, companies have received recent increased scrutiny by different Supervisory Exchanges internationally, such as the International Organization of Securities Commissions (IOSCO). In its recent publication dated February 2021, the IOSCO Board concluded that “there is an urgent need to work towards improving the completeness, consistency, comparability, reliability, and auditability of sustainability reporting – including greater emphasis on industry-specific quantitative metrics and standardisation of narrative information” (IOSCO, 2021, p.2).

While voluntary reporting remains the norm in most regions, individual jurisdictions have been making progress in enhancing corporate reporting on sustainability-related issues. The European Union, in particular, has emerged as a leader in this field with the enactment of the Non-financial Reporting Directive (NFRD) in 2018. However, there is an ongoing development of regulations aimed at establishing a comprehensive framework and standards for such disclosures.

This is the context that makes us believe that we are experiencing a very recent emphasis on climate disclosures and only in recent years most publicly available databases have started to collect companies’ emissions data.

b) Commodity prices

To contextualise our data set, we need to analyse whether the time series of 2014-2021 for the main commodities, such as crude oil prices and costs of renewable energy, is a relevant period to explain oil and gas sector returns in the context of carbon transition risk.

On one hand, the recent evolution of oil prices until 2021 exhibited in Figure 4-2 shows that the last pre-pandemic significant shock occurred in 2014, after a long period of higher prices. In our view, this period can be considered representative of the volatile market conditions inherent to the sector, including the consequences of the COVID-19 pandemic, from the first phase period characterised by lockdowns and economic slowdowns until the year 2021 when a "new normal" economic activity rebounded.

Figure 4-2
Brent oil price evolution 2013-2021

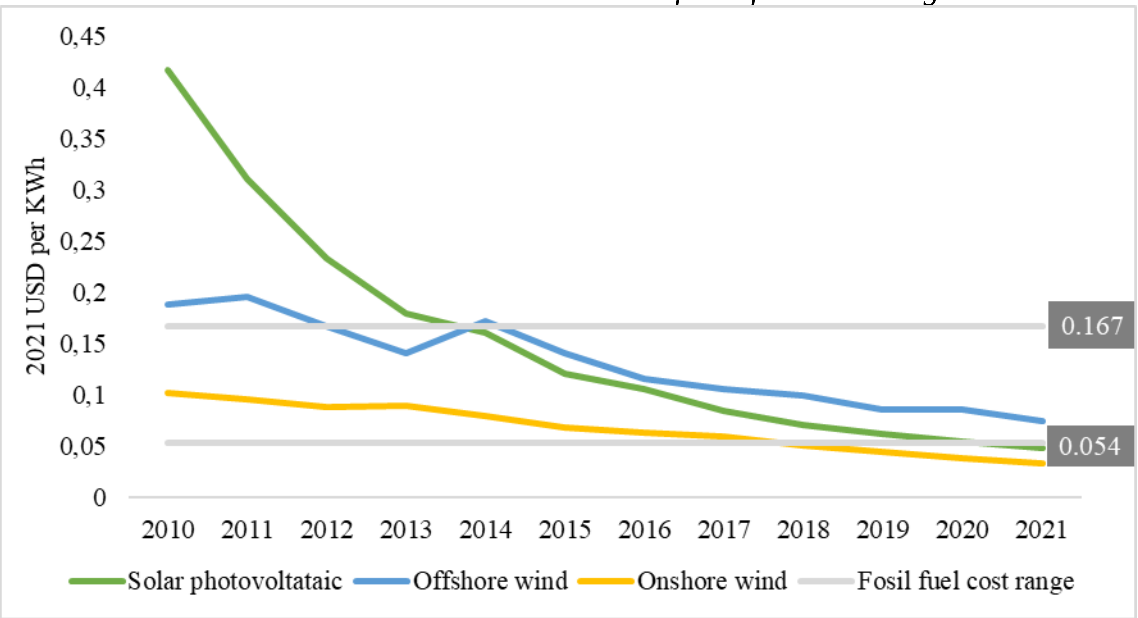
Source: Macrotrends[32]

On the other hand, the progressive cost reduction of renewable power generation technologies is the other market variable that is proving its competitiveness with other sources of energy. As reflected by IRENA (2022c), this process had already started in 2010, with a shift in the balance of competitiveness between renewables and fossil fuels and even nuclear options.

32 Macrotrends available at https://www.macrotrends.net/2480/brent-crude-oil-prices-10-year-daily-chart

In terms of generating electricity, onshore wind newly commissioned in 2010 was the sole renewable technology that experienced a decline in its weighted average levelised cost of electricity (LCOE) [33], within the range of new fossil fuel-fired power generation alternatives in the G20. Meanwhile, offshore wind and utility-scale solar photovoltaic technologies began to exhibit similar trends between 2012 and 2014, respectively (see Figure 4-3). This context provides sound grounds to consider 2014 a representative starting reference for our research based on the competitiveness of all these renewable energy sources.

Figure 4-3
Renewable Power Generation Costs 2010-2021 and fossil fuels cost range



Source: IRENA (2022c)

Closing remarks

Notwithstanding the purpose of our research, we cannot ignore that the energy scenario has suffered dramatic turmoil since 2021. First, due to the recovery of economic activity after COVID-19 lockdowns, energy prices escalated to pre-pandemic levels, and later, after Russia

[33] The LCOE of a particular technology is calculated by dividing its lifetime costs by its lifetime electricity generation, with both figures discounted back to a specified year using a discount rate that accounts for the average cost of capital (p.24). IRENA provides estimates for the cost range of fossil fuel-fired power generation across G20 countries and fuel types, ranging from USD 0.054/kWh and USD 0.167/kWh. All monetary values are expressed in real 2021 US dollars per kWh, which takes into account inflation (p.25).

invaded Ukraine in February 2022, we have been suffering another energy crisis, combining additional rises in prices and energy shortages.

Given these extraordinary circumstances, governments and policymakers are taking unprecedented measures, building a new energy security strategy to address disruption risks to phase out Russian fossil fuels and boost renewable energy production and energy efficiency measures to ensure affordability and self-sufficiency. A reference for that in the European Union is the REPowerEU plan and in the USA the Inflation Reduction Act of 2022.[34]

This new scenario, with almost no precedent in recent history, makes us believe that time and further analytical research are required to assess the implications for oil and gas companies in the transition to a lower carbon economy by 2022. In this context, given these limitations, we believe that the period 2014-2021 is a representative time reference for our research.

4.3 The data sources

Our database, therefore, covers the period 2014-2020 and 2021, where data are available, and consists of data sets collected from FactSet, Transition Pathway Initiative (TPI), and Bloomberg, as we will describe in more detail below.

(a) The carbon emissions database:

As mentioned previously, there is a limited number of databases that collect corporate disclosure data about sustainability metrics, such as carbon emissions. But it is also important to mention that, for our research, to focus on the oil and gas companies, a recognised methodology needs to be applied to the sector to make these companies comparable on a homogeneous basis and with power utility companies. Measuring carbon risk in the financial

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[34] For an overview description of REPowerEU see https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3131 and for the Inflation Reduction Act see https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/19/fact-sheet-the-inflation-reduction-act-supports-workers-and-families/

market requires the expertise and knowledge of specialised institutions dedicated to developing frameworks and benchmarks to compile carbon and transition-related information.

For this purpose, we have chosen the methodologies followed by a well-recognized and specialised institution, Transition Pathway Initiative (TPI), which also provides an open-access database, sourced from publicly disclosed company information provided by FTSE Russell, which makes the necessary adjustments to allow homogeneous data and comparability (TPI 2021a, 2021b). [35]

As a summary of the scope described in previous sections, the data set of companies is the following:

- Oil and gas companies:
    - Privately owned, based in Europe and North America, with only one state-owned company exception, which is based in Europe (Equinor, formerly Statoil, based in Norway)
    - Focused on the following segments:
        - Majors (IOCs) or integrated energy companies (IECs)
        - Independents, which are either independent upstream operators or fully integrated companies, like the Majors but smaller in size
        - Pure downstream companies, operating refineries, and retail networks
    - Carbon emissions intensity is measured in Scope 1, 2, and 3 bases
- Power utility companies:
    - Privately owned companies based in Europe and North America, including European state-owned companies, where the list is fuller

[35] The Transition Pathway Initiative Global Climate Transition Centre (TPI) is an independent source of research and data, established at the Grantham Research Institute on Climate Change and Environment, a global initiative supported by asset managers and led by asset owners. It is based at the London School of Economics and Political Science (LSE). Databases are available at https://www.transitionpathwayinitiative.org/sectors

- Carbon emissions intensity only coming from electricity generation

The database provided by TPI is on an annual basis and the latest and most complete carbon emissions data available at the time of our research reaches only until 2020. For research purposes, we have classified our assessment into four sets of companies, ensuring the selection fits with the scope described above:

- Oil and gas companies in Europe
- Oil and gas companies in North America (the USA and Canada)
- Power utility companies in Europe
- Power utility companies in North America (the USA and Canada)

(b) The renewable energy companies database

In this case, we start the process with the identification of pure renewable energy companies with Bloomberg Industry Classification Systems (BICS). For this purpose, we choose only renewable generation companies, consistent with the criteria previously established with power utility companies, and thereafter group them by European and North American portfolios. Finally, we group the portfolio of renewable energy generation companies with a market capitalisation above USD 200 million to ensure the liquidity of their stocks and filter those companies that investors may not focus on, given their relatively low size. Our methodology is aligned with the Imperial College Business School and IEA (2021) analysis of clean energy companies.

Given that the BICS classification system relies on revenue, operating income, and segment assets published in public reports and related company data, we would look for “Renewable Energy Generation”, which is a sub-sector within the broader “Electric Utilities” BICS sector. This sub-sector includes power energy companies that partially produce renewable energy in their energy mix. Therefore, to avoid the inclusion of companies already included in our portfolio of power utility companies, we filter them to firstly exclude companies already in that portfolio and secondly exclude those that did not correspond to pure renewable generation after verifying with their web pages their renewable energy characteristics.

(c) The financial metrics database:

We have selected FactSet to provide daily data on the stock returns of companies in each of the portfolios and to ensure the data connection with the TPI and Bloomberg BICS databases we have performed the matching using ISIN as the main identifier. Concerning the selection of the geographical area, the criteria selected in all databases is the domicile of the company´s headquarters.

The combined matching produced 35 oil and gas companies (25 for North America, 10 for Europe), 60 power utility companies (39 for North America, 21 for Europe), and 49 renewable energy producers (16 for North America, 33 for Europe).[36]

[36] See Appendix A for the full list of companies.

5 METHODOLOGY

5.1 Construction of the green factor to extend the Fama-French and Carhart asset pricing models

Based on the literature review, the capital asset pricing model (CAPM) developed by Sharpe (1964), the three-factor pricing model (Fama & French, 1993), the extended pricing model (Carhart, 1997) and the five-factor model (Fama & French, 2015) are all examples of linear factor models. These models assume that the returns of an asset can be explained by a linear combination of their underlying risk factors ($f_{k,t}$):

Formula 5-1

$$r_{t,i} = \alpha_i + \sum_{K=1}^{k} \beta_{k,i} f_{k,t} + \varepsilon_{t,i} \quad (5\text{-}1)$$

When we closely examine the climate finance literature to explain the cross-section of stock returns, under the assumption of factor models, we acknowledge that these models are based on portfolios rather than single stocks to obtain more stable betas (Petersen, 2009). Therefore, the return of the portfolio should be expressed thus:

Formula 5-2

$$r_{t,p} = \alpha_p + \sum_{K=1}^{k} \beta_{p,k} f_{t,k} + \varepsilon_{t,i} \quad (5\text{-}2)$$

and the variance:

Formula 5-3

$$\sigma_\rho^2 = \sum_{k=1}^{k} \beta_{\rho,k}^2 \sigma_k^2 + \sigma_{\varepsilon,\rho}^2 \quad (5\text{-}3)$$

As pointed out by Venturini (2022), the climate finance discussion resolves around understanding the inclusion of climate change risk dynamics into equations (5-1) and (5-2) as parameters such as “alpha” (α_p), “beta” ($\beta_{p,k}$) or the “variance” ($\sigma^2_{\varepsilon,p}$). The question is whether climate-related risks could be an anomaly that could lead to excess returns (“alpha”), an additional source of market risk that is factored in the financial market prices (“beta”), or a firm-specific characteristic that investors could mitigate through diversification (“variance”).

Based on equation 5.2 described above and following the current academic literature (Oestreich & Tsiakas, 2015; Bernardini et al., 2021; Hsu et al., 2022; Bolton & Kacperczyk, 2021a; and Gimeno & González, 2022), we construct a green factor to extend the Carhart (1997) asset-pricing model. We aim to analyse whether the green factor can better explain the return of the portfolio of energy companies and the existence of “alpha” or “beta” when compared with the traditional factors of the Fama-French and Carhart models.

Concerning the green factor, we describe the existence of a “green premium” or “greenium” as a measure of the added value of an environmentally friendly portfolio (“green”) in terms of market excess returns (“alpha”). The presence of a positive relationship in the cross-section between the stock returns of a high-carbon emitter portfolio and its associated high-carbon risk suggests that investors may be incentivized to hold such a portfolio and seek a reward, indicating the presence of a carbon risk premium.; in other words, another source of market risk priced in the financial market, which in the literature refers to “carbon beta”.

In this sense, we propose an energy transition factor (thereafter green energy transition factor, or green factor) based on our proxy to measure the carbon transition risk, the carbon emissions intensity, as described in Chapter 4 data process and sources. Carbon emissions intensity is defined as grams of CO_2 equivalent per megajoule, to reflect the extent to which energy companies produce carbon emissions per unit of energy generated.

The construction of our green factor requires building a high minus low pollution factor, shorting oil and gas shares with the highest carbon intensity and buying power utility shares with the lowest emissions intensity. A second version of the green factor is constructed by using renewable energy producers with zero emissions on the buying side.

The objective behind developing two versions of the green factor is to evaluate how the market responds to the speed of transition towards a low-emission business mix while constructing portfolios of oil and gas companies with a short position and portfolios with a long position in either of the following:

a) Power companies that have already initiated the shift to a low-emissions business mix before oil and gas companies (GF-Low), or

b) Renewable energy companies that are emissions-free and represent the final target of the transition (GF-Zero).

The model we propose represents the following time series regression:

Formula 5-4

$$r_{i,t} - r_f = \alpha + \beta_1(R_{M,t} - r_f) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \beta_5 GF_t + v_t \qquad (5\text{-}4)$$

where $r_{i,t}$ minus r_f is the excess return of portfolio *i* over the risk-free interest rate in day *t*, being the portfolios the following: a) the sample for the universe of energy corporations or b) the sample for the universe of utility corporations. GF_t is the time series value of the green factor. Returns from each portfolio are explained by the excess return in the market $R_{M,t}$ over the risk-free return, r_f, as well as by size, value, and momentum factors (SMB_t, HML_t, and MOM_t, respectively). The coefficients are estimated by a linear regression while v_t represents the residual. Robust standard errors are estimated under the Newey and West (1987) procedure. The literature employs this estimator to try to address the issues of autocorrelation and heteroskedasticity in the error terms of time series regression models that incorporate the Fama-French and Carhart factors.

Fama and French designed the three-factor model to capture the relationship between the average return on a security or a portfolio, where $(R_{M,t} - r_f)$ is the excess return on the value-weighted market portfolio over the risk-free interest rate, SMB_t, to denote size (market capitalisation, price times shares outstanding), which is the return differential between diversified portfolios of small stocks and big stocks, and HML_t to represent the value which is the return difference between diversified portfolios of high and low book-to-market price ratio stocks.

Carhart (1997) included the Momentum factor, MOM_t, in this model to denote the stock's tendency to continue moving in the same direction as the previous period. The factor MOM_t was constructed by taking the difference between the equal-weighted average returns of the highest and lowest-performing firms lagged by one month; which is commonly referred to as the winners minus losers factor.

The regression model requires the dependent variable $r_{i,t}$ daily closing prices for a representative sample of the universe of energy and utilities corporations in North America and Europe and, to be homogeneous, we reflect all prices in dollars.

For this purpose, we analyse the constituents of four indexes (FactSet code and number of constituents in parenthesis):

a) S&P 500 Energy (SPN01-SPX, 23) and S&P Composite 1500 Utilities (SP823, 55). These were used to represent the oil and gas and power utility sectors in North America, respectively.

b) Europe Energy Minerals (FS2100R3, 60) and Europe Utilities (FS4700R3, 96) which were applied to analyse the corresponding European oil and gas and power utility sector.

All prices of index components are in dollars and all indexes considered are exchange-traded. For North America, as the sample of energy corporations, we consider the S&P 500 Energy, which includes those companies comprising the S&P 500 that are classified within the GICs energy sector. For the universe of utility corporations, the S&P Composite 1500 Utilities includes those companies comprising the S&P 1500 that are included with the GICs utility sector.

Most financial industry benchmarks are based on the Global Industry Classification Standard (GICs) developed by Standard Poor´s and MSCI. The GIC energy sector includes companies involved in upstream, downstream, storage and transportation of oil and gas, and coal and consumable fuels. It also includes service and equipment companies for oil and gas firms. The GIC utility sector considers companies such as electric, gas, and water utilities. In addition, also comprises independent electric producers, energy trading firms and renewable energy companies involved in the generation and distribution of electricity.

We take the Europe Energy Minerals index (FS2100R3) and the Europe Utilities index (FS4700R3), compiled by FactSet, as representative samples of energy corporations in Europe. The constituents of the Europe Energy Minerals comprise companies engaged in oil and gas production, integrated oil companies, oil refining and marketing companies, and coal. The Europe Utilities index includes electric utilities, gas distributors, water utilities, and alternative power generation.

As a result, we form four portfolios with equal weights: Energy Europe, Utility Europe, Energy North America, and Utility North America. The number of companies considered in the entire energy sector sample is 83, comprising 23 in North America and 60 in Europe, while the utility sector sample totals 151, with 55 in North America and 96 in Europe. The data source for the whole sample is FactSet.

Kenneth French’s website s library provides data for the Fama-French three factors and the Carhart factor, as well as the risk-free rate[37]. However, the industry portfolios are only accessible for US stocks and are reported monthly. For this reason, we opt to use the whole market time series factors for North America and Europe, which also are available on a daily basis in the developed markets section of factors and returns. This approach is also preferable

[37] Data library available at https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

because it reduces the correlation with our industry-based green transition factor, given that the whole market factors are not industry-specific.

The model for the time series green factor GF_t is calculated in two versions. The first one is constructing: a) an equally weighted oil and gas portfolio and b) an equally weighted power utilities-based portfolio. The second one is constructing a) an equally weighted energy oil and gas portfolio and b) an equally weighted zero emitters renewable energy portfolio.

This framework allows us to find out whether this green factor provides relevant information on the portfolio returns for the universe of energy and utilities corporations that cannot be explained with other traditional factors. By constructing these two versions of the green factor, we aim to shed light on whether the differences between power utility companies that are in transition to a lower carbon energy mix and the pure renewable energy producers that already have zero carbon emissions could better explain energy and utility returns.

5.2 The green transition factor data

To construct the data for the green factor, we have selected FactSet to obtain daily data on the stock prices of the selected companies in each of the above-mentioned portfolios. The criteria used to identify the appropriate geographical area for each is the domicile of the company´s headquarters.

In the construction of the green factor, we have collected daily closing price data for the European and North American oil and gas corporations, and power utility firms, according to the criteria described in Chapter 4 and for which we have the carbon intensity database available from TPI for the 2014-2020 sample period. This delivers a sample with a maximum of 10 oil and gas corporates for Europe, which is matched with European power utility firms ranked on the bases of their carbon footprints. The same logic is applied to North American firms. The total number of North American oil and gas firms is 25. If the carbon intensity data is missing for a given year for a certain corporation, the firm is excluded from the portfolio.

We match the selected number of oil and gas North American firms with the corresponding power utilities ranked based on their carbon intensity.

While the number of firms considered changes due to certain missing data and to create the equally weighted portfolios, we can summarise the starting sample as follows: [38]

Table 5-1
Summary number of firms considered in long-short portfolios (2014-2020)

Geographical area and sector	Initial number of firms
European oil and gas	10
European power utility	21
European zero emitters	33
North American oil and gas	25
North American power utility	39
North American zero emitters	16

A second approach to constructing the green factor involves long positions in zero-emitters renewable energy producers. The BIC classification criteria deliver 16 corporations of these characteristics in North America. After we drop firms with missing data, we finally have 12 zero-emitting firms. We thus select the 12 most polluting firms from the sample of 25 North American oil and gas corporations yearly, based on the proposed carbon intensity measure. When we construct the zero-emitter portfolio for Europe, the method is slightly different. Given that there are 10 European oil and gas firms in our sample, we choose the top 10 zero emitters (from an initial sample of 33 sample firms), according to their market capitalisation.

Given that carbon intensity databases are reported annually and that there is a tendency to reduce carbon emissions over time among companies, but not uniformly, we recalibrate

[38] See appendix A for the detail of the portfolios and their constituents.

annually the portfolios and for each year the selected firms are different. In this context, there is a certain discrepancy as some streams of literature argue that there is no need to constantly recalibrate the portfolios (e.g., Gimeno & Gonzalez 2022**)** and some claim the opposite, such as Bernardini et al. (2021) and Görgen et al. (2020).

6 EMPIRICAL RESULTS

6.1 The performance of the long-short portfolios and the green factor

The construction of our green factor can be interpreted as an investment strategy focused on energy companies when investors take a long position in companies producing energy with lower or zero carbon intensity and a short position in energy companies with higher carbon intensity.

With the Transition Pathway Initiative (TPI) carbon intensity database, we sort companies yearly for each geographical area (North America and Europe) by their carbon intensity metric and select the oil and gas corporates with the most polluting record for the short position. We simultaneously create a long position with the power utility corporations bearing the lowest carbon intensity reported metrics.

As a means of the robustness of our analysis and to measure the market´s response to the speed of transition, we create an alternative green factor. This factor is constructed using long positions in zero-emitting renewable energy producers and short positions in the most polluting oil and gas companies for each of the geographical areas under consideration. We expect that using long positions on zero emitters will outperform its low carbon utilities counterparts, as investors will prefer investment in advanced zero-emission technologies. This second approach requires the selection of renewable energy producers with the Bloomberg Industry Classification System (BICS) for the long position.

Once firms have been classified as low-carbon power utilities or zero emitters and high polluters of oil and gas, we form equally weighted portfolios. As follows, we report profitability from the above-mentioned portfolios. Cumulative returns are then calculated for long-only and long-short positions.

As the first step with long-only portfolios, Figures 6-1, 6-2, and 6-3 report the time series evolution of investment in each of the six portfolios considered for Europe and North America (EU and NA thereafter), i.e., NA low emitter, NA high polluter, EU low emitter and EU high polluter, NA Zero-emitter, and EU Zero-emitter.

Figure 6-1
Cumulative returns in NA: Long only low-carbon power utilities and long only high-polluting O&G

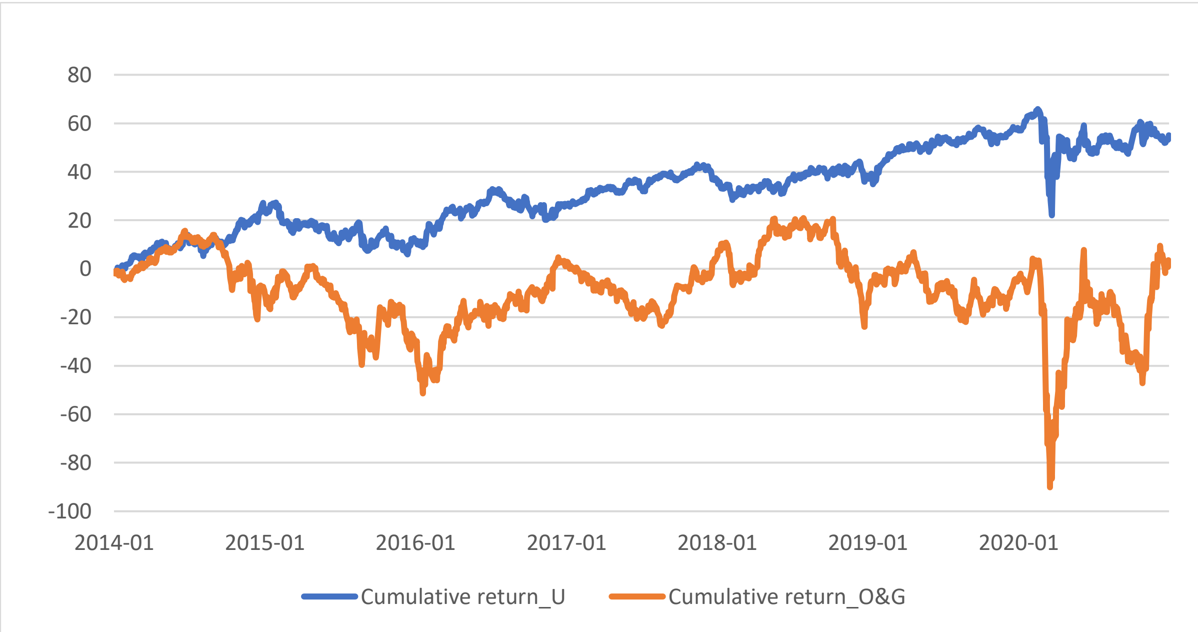


Figure 6-2 *Cumulative returns in EU: Long only low-carbon power utilities and long only high-polluting O&G*

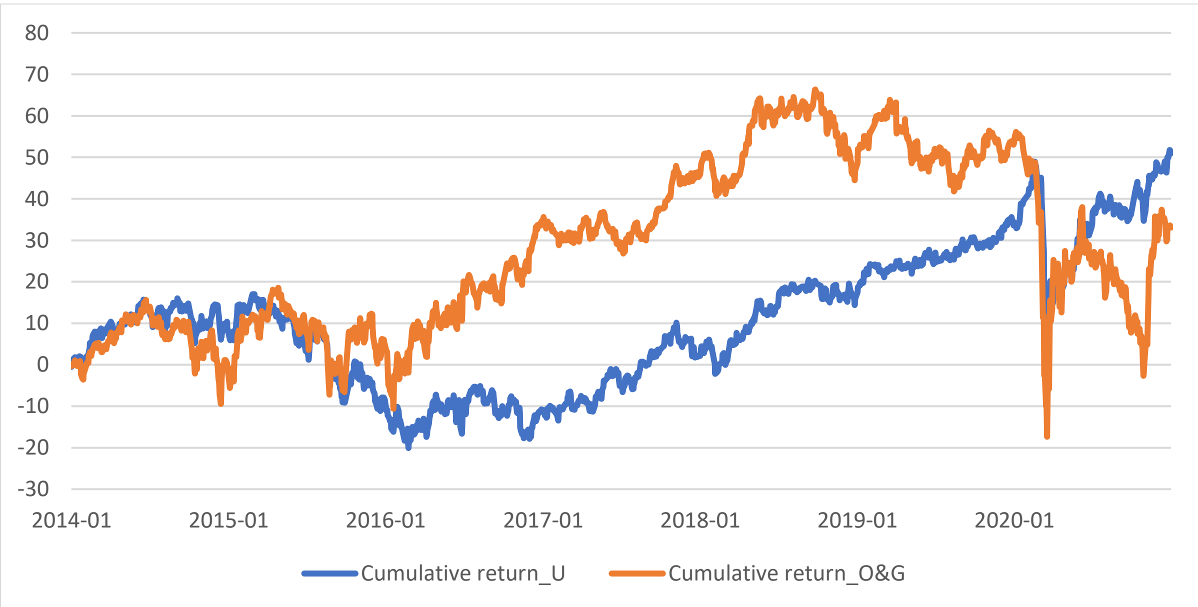
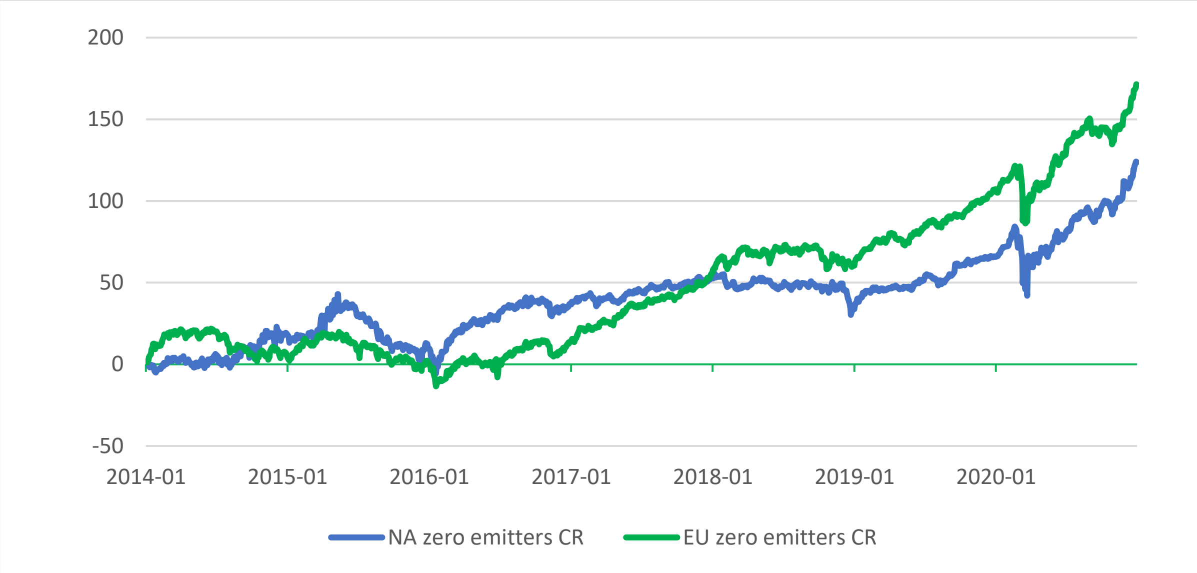


Figure 6-3

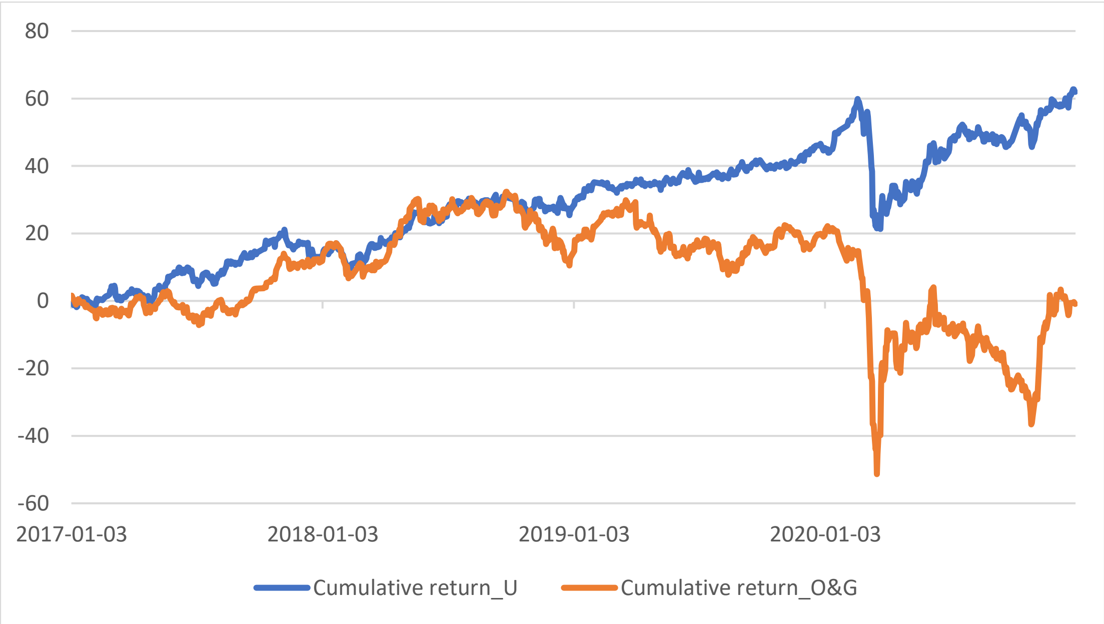
Cumulative returns in NA and EU: Long only renewable energy zero emitters



We can see a common feature across all portfolios. The profitability decreases during the 2014-2015 crude oil price collapse and during the 2020 COVID-19 crisis for all portfolio types. This is consistent with the reported patterns in the literature (see Pastor et al., 2022 and Gimeno, & Gonzalez, 2022). The general result for the NA case is that long-only investments in low-carbon power utility companies and zero-emitter renewable energy producers deliver higher cumulative returns than long-only investments in high-polluting oil and gas corporations. For European-based corporations, the outperformance of cleaner energy companies becomes evident only after 2020. Aligned with the results of Gimeno and Gonzalez (2022), we report a change in the sign in the evolution of returns, with predominant negative returns during the first part of the sample, shown in Figures 6-1 and 6-2. Cumulative returns for the zero emitters, reflected in Figure 6-3, are, however, positive during most of the sample period. Important exceptions include short episodes in the 2014-2016 period, predominantly driven by a collapse in commodity markets and subsequent credit risk in energy corporations. Interestingly, the EU long-only portfolio of zero emitters outperforms its NA counterpart from December 2017. This could be related to the start of the US Fed rate increases and the shifted positions under Trump’s presidency, with the announcement in June 2017 of the withdrawal from the Paris Agreement and subsequent approvals of oil and gas developments, as in the case of drilling in the Arctic or new pipelines between Canada and the USA.

These changing results in 2017 led us to reformulate the time series for the European portfolio starting this year, as reflected in Figure 6-4. It shows that 2017 is a turning point for the EU portfolio, as long-only power utility firms perform better than their oil and gas counterparts, which is also similar to the result obtained for the same portfolio, observed in Figure 6-1 for North America. Therefore, we can conclude with common coincidences for both geographies only since 2017, and differences between the period 2014-2016 could be explained in the same way as the outperformance of the EU zero emitters, mentioned above.

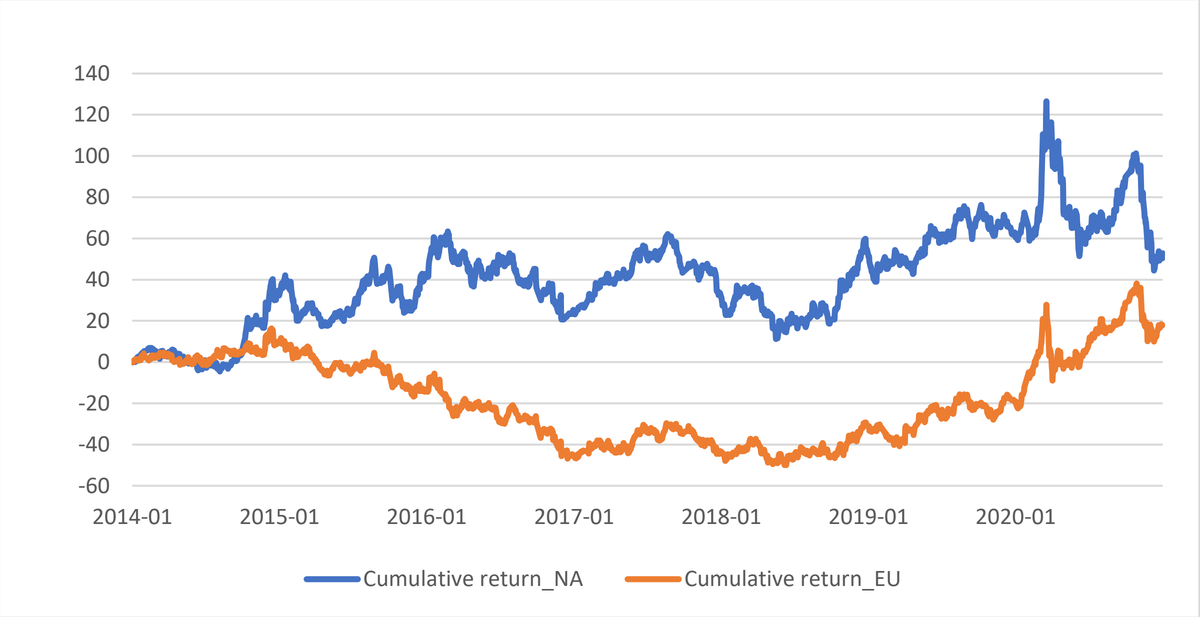
Figure 6-4
Cumulative returns in EU since 2017: Long only low-carbon power utilities and long only high-polluting O&G



The second step for the analysis is to obtain the results for the long-short portfolios. We define the cumulative return of the green factor as the cumulative return of portfolios for long cleaner energy and short high-polluting oil and gas corporations. This way, we have two sets of results for the green factor: a) long low-carbon power utility companies and short high-polluting oil and gas corporations, and b) long zero-emitter renewable energy companies and short high-polluting oil and gas corporations.

The evolution of the green factor based on low-carbon utility companies is provided in Figure 6-5. A close look at the graph, which exhibits the time series evolution of cumulative returns of the green factor, shows that while outperformance is clear from 2015 for the North American case, positive profitability of the green factor in Europe is only documented from 2020. This suggests that the collapse of stock prices in oil and gas corporations during the COVID-19 crisis and pronounced recovery in its aftermath (in relation to the low-carbon utility counterparts) was stronger in Europe than in North America. Results are also consistent with an enhanced climate change awareness in the aftermath of the COVID-19 crisis and the strong policy support in the EU under the introduction of the New Green Deal in December 2019, the EU Recovery Plan ("Next Generation EU") in November 2020, and the Fit-for-55 thereafter in 2021. Negative cumulative returns of the green factor are also predominant during the 2000-2010 period in the work of Gimeno and González (2022).

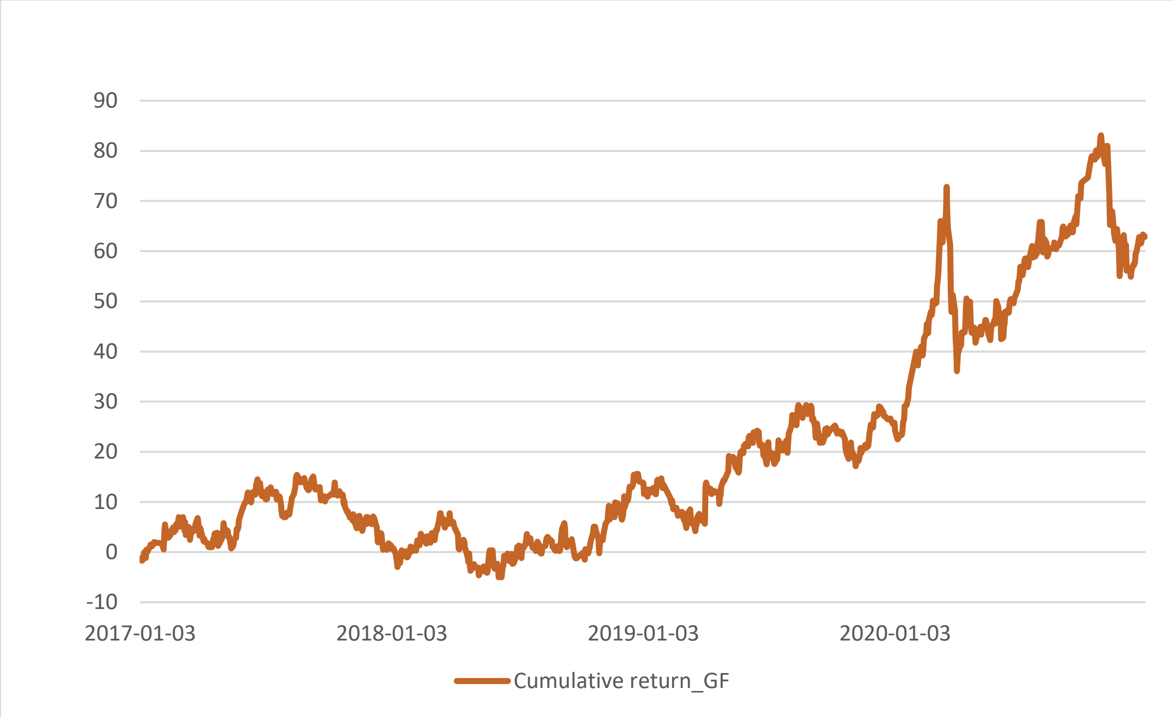
Figure 6-5
Green Factor based on low-carbon power utilities in NA vs. EU



As a matter of reference, Figure 6-6 reflects the positive cumulative performance of the EU green factor with low carbon power utilities when considering the starting point since 2017.

Figure 6-6

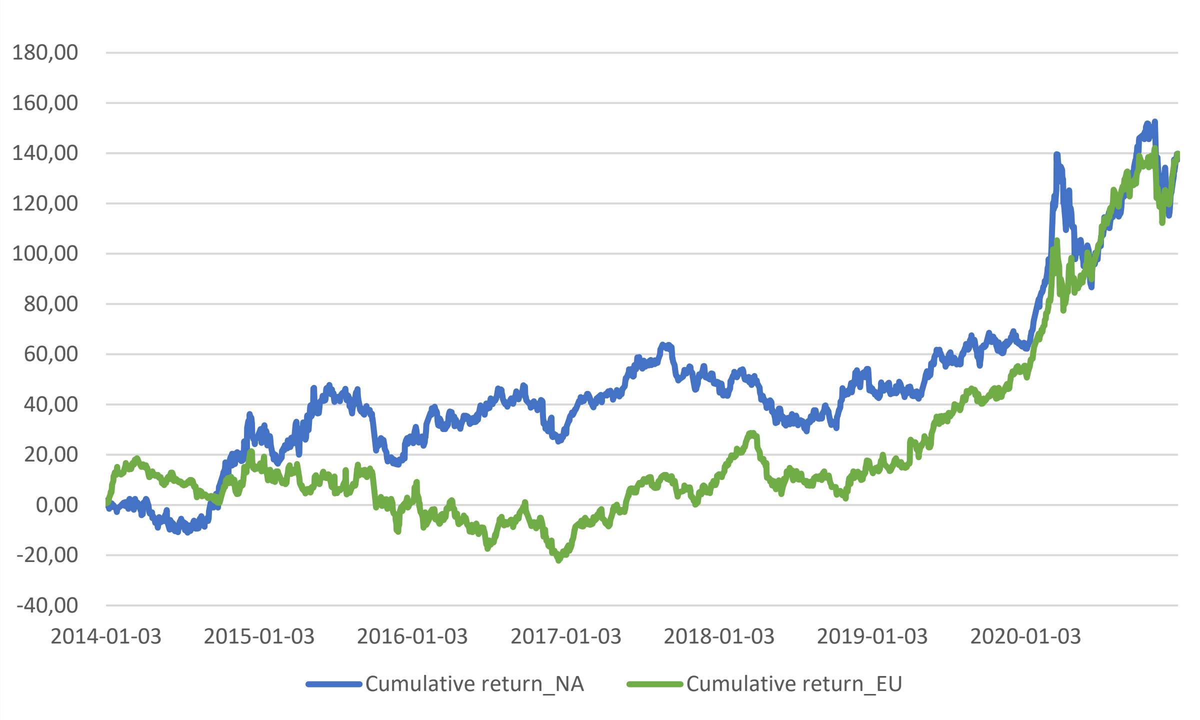
Green Factor in EU since 2017 based on low-carbon power utilities



The time series evolution of the green transition factor for the zero emitters case is illustrated in Figure 6-7. A close inspection of this figure suggests that cumulative returns under this portfolio are on average higher and less volatile than under the low-carbon utility counterpart illustrated in Figure 6-5. as well as a closer performance of the NA and EU cases. Cumulative returns are negative in the case of the EU green factor for zero emitters for a shorter period (namely Nov 2015-May 2017) than in the green factor for power utilities, as reflected in Figure 6-5.

Figure 6-7

Green Factor based on zero emitters in NA vs. EU



The performance of the low carbon emissions and zero emissions-based green transition factors are quantified in the upper and lower panels of Table 6-1, respectively.

Table 6-1

Descriptive statistics NA vs EU (2014-2020): cumulative returns of the green factor portfolio

		Green transition factor based on low-carbon power utilities					
(%)	Mean	Stdev	Sharpe	Max	Min	Skew	Kurtosis
NA	7.81	33.93	0.23	21.56	-16.89	-0.04	13.67
t-stat	1.72*						
EU	2.65	20.87	0.13	10.32	-9.82	-0.54	8.46
t-stat	1.68*						
		Green transition factor based on zero emitters					
NA	20.44	30.58	0.67	14.30	-18.10	-0.26	11.53
t-stat	1.74*						
EU	20.66	23.72	0.87	10.89	-13.90	-0.96	12.13
t-stat	2.27**						

Note: This table presents cumulative results of the green transition factor in North America and Europe during 2014-2020, in its two versions: a) as a portfolio with a long position in low carbon power utilities and a short position with high polluting oil and gas corporations and b) as a portfolio with a long position in zero emitters renewable energy producers and a short position in high polluting oil and gas corporations. With the t-statistics, it is tested the null hypothesis that the return data comes from a normal distribution with a mean equal to zero. Thus, the alternative hypothesis is that the return distribution does not have a mean equal to zero with a certain significance level. The asterisks *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

In Table 6-1, we describe average profitability measures obtained from daily price data for the whole sample considered. Results in the upper panel show that while the average performance of the green factor based on low carbon utilities is positive for both North America and Europe, risk-adjusted returns, as measured by the Sharpe ratios, remain highest for the NA long-short portfolio. Reported evidence is consistent with the idea that increasing climate change awareness in recent years has shifted investor demand towards green assets. This is true since 2015 for the North American case and in the post-COVID-19 era in the case of Europe. As noted previously, it is worth noting that if considering the European green factor since 2017, its cumulative return is positive and, as described in Table 6-2, its average return reaches 16.27% with a 0.73 Sharpe ratio, clearly outperforming the whole 2014-2020 series with 2.65% average return and 0.13 Sharpe ratio.

Table 6-2

Descriptive statistics in EU (2017-2020): cumulative returns of the green factor based on low carbon power utilities

Green transition factor based on low carbon power utilities							
(%)	Mean	Stdev	Sharpe	Max	Min	Skew	Kurtosis
EU since 2017	16.27	22.36	0.73	10.32	-9.82	-0.47	9.63
t-stats	1.85*						

Note: This table presents cumulative results of the green transition factor in Europe during 2017-2020, as a portfolio with a long position in low-carbon power utilities and a short position with high-polluting oil and gas corporations. With the t-statistics, it is tested the null hypothesis that the return data comes from a normal distribution with a mean equal to zero. Thus, the alternative hypothesis is that the return distribution does not have a mean equal to zero with a certain significance level. The asterisks *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Results reported in the lower panel in Table 6-1 show that the green factor, based on zero emitters, delivers its outperformance with respect to the low-carbon power utilities counterpart for both NA and EU. The improved performance arises from significantly higher average returns in relation to volatility. Average returns in the green transition factor increased from 7.81% and 2.65% in the low carbon utilities portfolio, in NA and EU respectively, to 20.44% and 20.66% in the zero emitters portfolio. There is therefore a notable difference for the EU case. The reported positive performance of both measures of green transition factors is consistent with the green factor literature (see Gimeno & González, 2022; Ilhan et al., 2021) and also suggests that investors require compensation for transition risk.

One open question relates to the time lapse between available carbon emissions and the calculation of the portfolio returns. In our analysis, we use carbon emissions intensity data in year t to account for daily returns over the same year t. However, this approach may introduce a look-ahead bias, where we might inadvertently relate stock returns during year t to emissions data that may not have been accessible to investors at that time. To address this concern, we followed a robustness check and calculate portfolio returns in year t with the carbon emissions data in year t-1, to reflect the time lapse when emissions are released. Reported results in Table 6-3 and Figure 6-8 reveal that the results are robust to the use of the lagged value of the carbon intensity measure, but do not improve the statistical significance.

In our case, this means that new information about carbon emissions intensity for year t is reflected progressively over the year in share returns and therefore there are limited lagging effects. These results are consistent with those of Kacperczyk et al. (2016), which demonstrate that when interpreting results using lagged share returns, investors tend to pay limited attention and do not promptly integrate new information at the company level.

Table 6-3

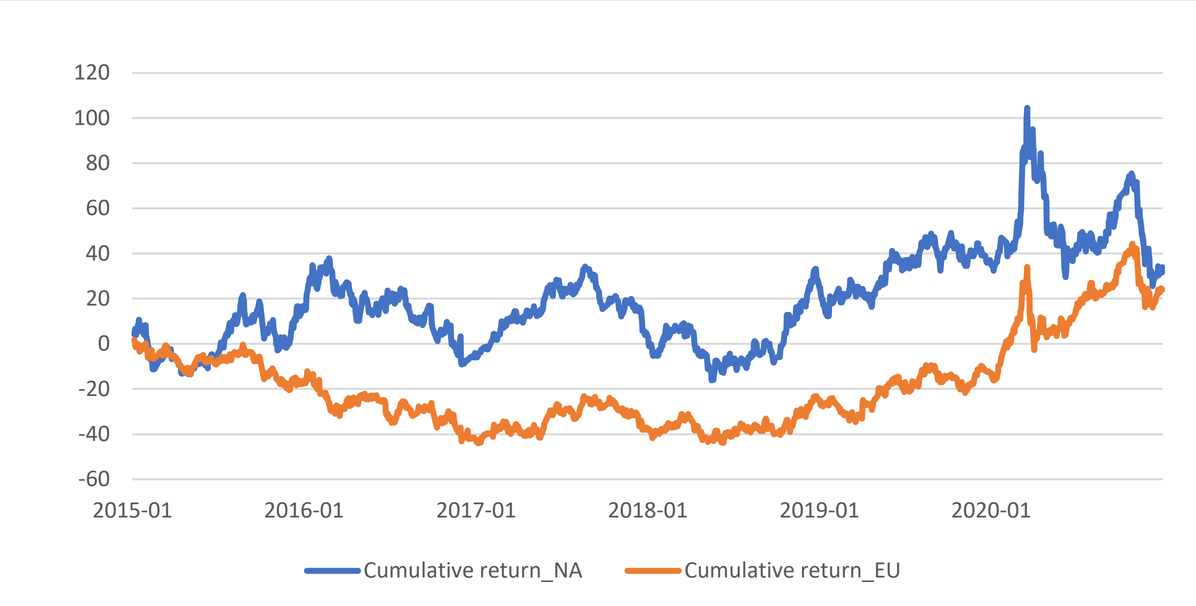
Descriptive statistics lagged 1 year NA vs.EU (2014-2020): cumulative returns of the green factor portfolio based on low carbon power utilities

	Green transition factor based on low carbon power utilities						
(%)	Mean	Stdev	Sharpe	Max	Min	Skew	Kurtosis
NA	5.86	34.69	0.17	18.50	-15.16	-0.22	9.97
t-stats	1.72*						
EU	4.15	21.82	0.19	10.32	-9.82	-0.63	8.59
t-stats	1.79*						

Note: This table presents cumulative results of the green transition factor in North America and Europe during 2014-2020, as a portfolio with a long position in low-carbon power utilities and a short position with high-polluting oil and gas corporations. In this robustness test, the portfolio is formed based on the ranking of carbon intensity in year t-1 and cumulative returns in year t, starting in 2015. With the t-statistics, it is tested the null hypothesis that the return data comes from a normal distribution with a mean equal to zero. Thus, the alternative hypothesis is that the return distribution does not have a mean equal to zero with a certain significance level. The asterisks *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Figure 6-8

Green Factor lagged 1 year based on low-carbon power utilities in NA vs. EU



6.2 Measuring the effect of the green transition factor as an explanatory variable of corporate performance

We now proceed to analyse the effect of the green transition factor as an explanatory variable of corporate performance for the sample of the universe of both energy and utility corporations in Europe and North America (EU and NA thereafter).

For this purpose, we construct two portfolios for each geographical area, one with the sample of all the energy sector, including oil and gas corporations, traded in the NA and EU areas, and a second one with the sample of all the utility sector including power utility firms under both areas. Equally-weighted portfolios of energy and utilities are formed with the following four indexes: a) S&P 500 Energy (SPN01-SPX, 23) and S&P Composite 1500 Utilities (SP823, 55), to represent all energy corporations and all utility firms in North America, respectively, and b) Europe Energy Minerals (FS2100R3, 60) and Europe Utilities (FS4700R3, 96), applied to analyse the corresponding European energy and utility corporates, respectively. FactSet code and number of constituents are shown in parentheses.

These energy and utility portfolios are then regressed against the simple Carhart (1997) four-factor model as well as the extended Carhart framework with the green transition factor, as specified in equation (5-4), described in Chapter 5 Methodology.

Time series results for the energy portfolio (the dependent variable) are reported in Tables 6-4 and 6-5. Results in Table 6-4 measure and explain the influence of the green transition factor based on short high polluting oil and gas, long on low carbon power utilities portfolio, while Table 6-5 shows that on short high polluting oil and gas, and long on zero emitters from renewable energy.

Panel A in Tables 6-4 and 6-5 demonstrates that the inclusion of the green transition factor has a significant impact on the portfolio returns of North American energy corporations. The second column of panel A shows that the green transition factor has a negative and statistically significant effect on the energy portfolio returns, suggesting that investors are punishing companies in the oil and gas sector. The inclusion of the green transition factor is also reflected in a change in the reported alpha when the results of column 1 and column 2 are compared. Indeed, while the estimated alpha is negatively and statistically significant under column 1, it becomes negative but not statistically significant under column 2. The measurement of transition risk through the proposed risk factor also leads to an increase in the adjusted R^2 which moves from 0.71 in column 1 to 0.85 in column 2. The adjusted R^2 (adj. R^2) takes into account the number of independent variables used to explain the dependent variable. By doing so, we can determine if adding new variables to the model improves the model fit. Accounting for the new green factor, based on low-carbon power utilities, also leads to lower market risk, value, size, and momentum effects. The decrease in the parameter values corresponding to momentum, market, and size factors is higher than 20%. In the case of the new factor based on zero emitters, the inclusion of the green factor leads to combined effects with a decrease in the effect of market risk, value, and momentum factors but an increase in the impact of the size factor.

Panel B, in the last two columns of Tables 6-4 and 6-5, reports estimated coefficients for the benchmark and extended model under the European energy portfolio. Regression results demonstrate that the green transition factor has also a negative and significant effect on the European energy portfolio returns. The impact on portfolio returns is, however, lower than that reported for the North American case. This can be seen in the estimated size of the coefficient corresponding to the green transition factor, the adj. R^2, and the estimated alpha. The estimated coefficient of the green factor based on low carbon power utilities in column 4 is -0.34, 0.20 points lower in absolute value than that reported for the North American case. The reported adj. R^2 under column 4 is 0.7. While this is 0.07 points higher than that estimated under the benchmark case (see column 3), the difference in the goodness of fit of the regression arising for the new factor is twice for the North American estimate, since it is 0.14 points higher than its benchmark case. Lastly, we see no significant difference between the alpha coefficients reported in columns 3 and 4. Note that the inclusion of the green transition factor based on low-carbon power utilities reduces the significance of the momentum factor and moderately decreases the effect of the value and the market factors but increases the impact of the size factor. It can however be noted that the green factor based on zero emitters eliminates the significance of the momentum factor and decreases the impact of the value but increases the effect of size and market factors. The estimated beta for the green factor in column 2 for North America shows -0.35, only 0.07 points higher in absolute value than that reported in column 4 for the European case.

The relationship between the green factor and the value and momentum factors has been addressed by Pastor et al. (2022), who show that 80% of the value´s alpha and all the momentum´s alpha disappear after controlling for the strong performance of the green factor.

These results are consistent with those reported in Table 6-1, which shows a clear outperformance of the green factor based on low-carbon power utilities in North America when compared to the European case; also shows an almost equal performance of the green factor based on zero emitters between North America and Europe.

Table 6-4
Carhart (1997) based regressions for the energy portfolios and with the green transition factor (based on low-carbon power utilities)

	Panel A NA energy portfolio		Panel B EU energy portfolio	
Alpha	-0.062*	-0.028	0.002	-0.002
	(-1.90)	(-1.19)	(0.1)	(-0.10)
MKT	1.269***	0.973***	1.047***	0.979***
	(43.6)	(43.53)	(40.37)	(41.09)
SMB	0.517***	0.275***	0.346***	0.425***
	(9.05)	(6.60)	(5.87)	(7.49)
HML	0.479***	0.403***	0.693***	0.424***
	(8.32)	(9.67)	(11.82)	(7.69)
MOM	-0.928***	-0.461***	-0.137***	-0.073**
	(-21.01)	(-13.54)	(-3.46)	(-2.01)
GREEN		-0.542***		-0.338***
		(-39.42)		(-18.98)
Adj.R^2	0.71	0.85	0.63	0.70

Table 6-5
Carhart (1997) based regressions for the energy portfolios and with the green transition factor (based on zero-emitters)

	Panel A NA energy portfolio		Panel B EU energy portfolio	
Alpha	-0.062*	-0.028	0.002	0.013
	(-1.90)	(-0.95)	(0.1)	(0.61)
MKT	1.269***	1.143***	1.047***	1.084***
	(43.6)	(42.21)	(40.37)	(45.25)
SMB	0.517***	0.576***	0.346***	0.569***
	(9.05)	(11.15)	(5.87)	(10.20)
HML	0.479***	0.409***	0.693***	0.504***
	(8.32)	(7.84)	(11.82)	(9.16)
MOM	-0.928***	-0.681***	-0.137***	-0.015
	(-21.01)	(-16.27)	(-3.46)	(-0.41)
GREEN		-0.346***		-0.275***
		(-19.63)		(-17.47)
Adj.R^2	0.71	0.85	0.63	0.69

Note: Tables 6-4 and 6-5 present panel results for the energy sector portfolios regressed against the simple Carhart (1997) four-factor model and extended with the green transition factor, GREEN (built in Table 6-4 as a portfolio long with the low carbon power utilities and short with high polluting oil and gas corporations, while in Table 6-5 built as a portfolio long with the zero emitters renewable energy producers and short with high-polluting oil and gas corporations). The other factors are MKT (market excess return over the risk-free return); Fama & French (1993) SMB (small minus big) and HML (high minus low) and Carhart (1997) MOM (winners minus losers). The left column shows the regression results for the North American portfolio, while the right column shows the results for the European portfolio. The t-statistics in parentheses are based on Newey-West (1987) standard errors. The asterisks *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

The overall conclusion that can be obtained from Tables 6-4 and 6-5 is that the energy transition requires a greater reliance on low-carbon technologies, which has the impact of lowering expected returns on energy companies. This implies that the green transition factor can explain the evolution of the stock prices of energy corporations.

Time series results for the utility portfolio (the dependent variable) are reported in Tables 6-6 and 6-7. Results in Table 6-6 measure and explain the influence of the green transition factor based on short high polluting oil and gas, long on low carbon power utilities portfolio, while Table 6-7, on short high polluting oil and gas, long on zero emitters renewable energy producers portfolio.

Reported results in columns 2 and 4 demonstrate that the green transition factor has a positive effect on returns in utility companies in both of the geographical areas considered, with investors rewarding companies that are known to invest in the green transition. The size of the coefficient corresponding to the green factor is greater for the NA than for the EU areas. However, a comparison of the estimates in the last row of Tables 6-6 and 6-7 shows that the absolute values of the green transition factor are notably higher for energy portfolios than for utility portfolios. The return penalisation for the oil and gas sector is greater than the reward obtained by companies in the utility sector. Reported market betas are much lower than those shown in Tables 6-4 and 6-5, reflecting the fact that utility corporations are defensive stocks. The impact of the size factor is much lower than that reported in Tables 6-4 and 6-5. In fact, the size factor is not significant for the NA case, as shown in column 2 of Table 6-6. The inclusion of the green factor in the NA utility portfolio eliminates the size effect and changes the sign of the momentum factor. When the green transition factor is included, there is a change of sign on the momentum effect on portfolio returns for NA utilities.

In the case of the EU utilities portfolio, the impact of the momentum variable does not vary significantly under the inclusion of the green transition factor. The sustainability-related literature has generally reported a negative sign for the momentum variable (see Edmans, 2011). However, positive momentum effects have been identified in panel regressions (see Hallbritter et al., 2015).

The inclusion of the green factor significantly increases the goodness of fit of the regression, as can be observed by comparing columns 1 and 2, reflecting the NA utility portfolio. The increase in adj. R^2 is not as important when we compare the regressions for the EU utility portfolios in columns 3 and 4 of Tables 6-6 and 6-7. Indeed, the size of the green transition coefficient is notably lower. The lower performance for the EU case may be related to the lower profitability delivered by the European green transition factor long-short portfolio with low carbon utilities, as reported in Table 6-1.

Table 6-6
Carhart (1997) based regressions for utility portfolios and with the green transition factor (based on low-carbon power utilities)

	Panel A NA utility portfolio		Panel B EU utility portfolio	
Alpha	-0.005	-0.014	-0.004	-0.003
	(-0.5)	(-1.54)	(-0.58)	(-0.54)
MKT	0.289***	0.362***	0.371***	0.375***
	(30.87)	(42.97)	(50.40)	(50.69)
SMB	*-0.058****	*0.001*	0.164***	0.159***
	(-3.18)	(0.08)	(9.76)	(9.57)
HML	0.159***	0.177***	0.102***	0.120***
	(8.58)	(11.30)	(6.11)	(7.00)
MOM	*0.054****	*-0.062****	0.056***	0.052***
	(3.79)	(-4.79)	(5.01)	(4.62)
GREEN		0.134***		0.023***
		(25.81)		(4.17)
Adj.R^2	0.40	0.57	0.65	0.66

Note: This table presents panel results for the utility sector portfolios regressed against the simple Carhart (1997) four-factor model extended with the green transition factor, GREEN (built as a portfolio long with the low carbon power utilities and short with high polluting oil and gas corporations). The other factors are MKT (market excess return over the risk-free return); Fama & French (1993) SMB (small minus big) and HML (high minus low) and Carhart (1997) MOM (winners minus losers). The left columns are the regressions for the North American portfolio and the right columns are for the European. The t-statistics in parentheses are based on Newey-West (1987) standard errors. The asterisks *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 6-7

Carhart (1997) based regressions for utility portfolios and with the green factor (based on zero emitters)

	Panel A NA utility portfolio		Panel B EU utility portfolio	
Alpha	-0.005	-0.011	-0.004	-0.004
	(-0.5)	(-1.09)	(-0.58)	(-0.68)
MKT	0.289***	0.3107***	0.371***	0.367***
	(30.87)	(33.14)	(50.40)	(50.03)
SMB	-0.058***	-0.069***	0.164***	0.151***
	(-3.18)	(-3.83)	(9.76)	(8.79)
HML	0.159***	0.171***	0.102***	0.112***
	(8.58)	(9.46)	(6.11)	(6.64)
MOM	*0.054****	*0.011*	0.056***	0.050***
	(3.79)	*(0.76)*	(5.01)	(4.32)
GREEN		0.060***		0.016***
		(9.78)		(3.26)
Adj.R^2	0.40	0.43	0.65	0.69

Note: This table presents panel results for the utility sector portfolios regressed against the simple Carhart (1997) four-factor model extended with the green transition factor, GREEN (built as a portfolio long with the zero emitters renewable energy producers and short with high polluting oil and gas corporations). The other factors are MKT (market excess return over the risk-free return); Fama & French (1993) SMB (small minus big) and HML (high minus low) and Carhart (1997) MOM (winners minus losers). The left columns are the regressions for the North American portfolio and the right columns are for the European. The t-statistics in parentheses are based on Newey-West (1987) standard errors. The asterisks *, **, and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 6-7 reports the results for utility corporations when the green transition factor is constructed with renewable energy companies that are zero emitters. A comparison between Table 6-6 and Table 6-7 does not show significant differences between regression estimates when the low carbon and zero emitter portfolios are compared for the EU case. The estimated coefficient corresponding to the zero emitters' green transition factor in the NA case is 0.06 and therefore significantly lower than that reported in Table 6-6, which is significant and equal to 0.134. The inclusion of the green transition factor with zero emitters does not have a notable increase in the adj. R^2, as was the case for the NA portfolio in Table 6-6.

The green factor is, however, generally not more highly correlated than the other benchmark factors. Indeed, correlation results between the factors in the Fama-French five-factor model are recognised by the authors Fama and French (2015), and our results in Tables 6-8 and 6-9 show that the correlation between the value and momentum factors exceeds those observed by the green factor. The highest correlation of the green factor relates to its positive relationship with the momentum factor, which has also been explained previously, and the negative correlation with the value factor is also consistent with the findings of Pastor et al. (2022), reflecting the fact that value stocks are more often brown than green.

Table 6-8 reports the correlation matrix among the Fama-French three factors plus the Carhart momentum factor and the green factor based on the power utilities and Table 6-9 shows those with the green factor based on zero emitters renewable energy.

Table 6-8
Correlation matrix between the green factor based on the power utilities portfolio and the rest of the factors

North America					
	Green factor	MKT	SMB	HML	MOM
Green factor	1,00				
MKT	-0,35	1,00			
SMB	-0,25	0,12	1,00		
HML	-0,39	0,13	0,08	1,00	
MOM	*0,51*	-0,09	-0,21	*-0,70*	1,00
Europe					
	Green factor	MKT	SMB	HML	MOM
Green factor	1,00				
MKT	-0,31	1,00			
SMB	0,22	-0,50	1,00		
HML	*-0,44*	0,32	-0,21	1,00	
MOM	0,36	-0,28	0,22	*-0,64*	1,00

Note: This table presents correlation results between the green transition factor, built as a portfolio long with low carbon power utilities and short with high polluting oil and gas corporations, and the rest of the factors. The other factors are MKT (market excess return over the risk-free return); Fama & French (1993) SMB (small minus big) and HML (high minus low) and Carhart (1997) MOM (winners minus losers).

Table 6-9
Correlation matrix between the green factor based on the zero emitters renewable energy portfolio and the rest of the factors

North America					
	Green factor	MKT	SMB	HML	MOM
Green factor	1,00				
MKT	-0,25	1,00			
SMB	-0,06	0,12	1,00		
HML	-0,38	0,13	0,08	1,00	
MOM	*0,46*	-0,09	-0,21	*-0,70*	1,00
Europe					
	Green factor	MKT	SMB	HML	MOM
Green factor	1,00				
MKT	-0,16	1,00			
SMB	0,29	*-0,50*	1,00		
HML	-0,39	0,32	-0,21	1,00	
MOM	0,39	-0,28	0,22	*-0,64*	1,00

Note: This table presents correlation results between the green transition factor, built as a portfolio long with the zero emitters renewable energy producers and short with high polluting oil and gas corporations, and the rest of the factors. The other factors are MKT (market excess return over the risk-free return); Fama & French (1993) SMB (small minus big) and HML (high minus low) and Carhart (1997) MOM (winners minus losers).

6.3 The green transition factor as a potential source of excess return

We now proceed to analyse the extent to which the green transition factor generates alpha. This means that there are positive and significant excess returns in a portfolio that has a long position in companies producing energy with lower or zero carbon intensity and a short position in energy companies with higher carbon intensity.

We have previously demonstrated that the green transition factor is significant in explaining returns. The next step is to quantify the extent to which the described portfolio generates alpha or abnormal returns that cannot be explained by the benchmark factors prominent in the asset pricing literature.

To achieve this objective, we adopt the methodology commonly employed in the green factor research. Notable works that have followed this approach include Oestreich and Tsiakas

(2015), Bernardini et al. (2021), Hsu et al. (2022), and Gimeno and González (2022). In the field of ESG, we can refer to Halbritter et al. (2015).

Thus, we analyze the extent to which the green transition factor exhibits alpha by estimating the following time series regression:

Formula 6-1

$$GF_t = \alpha + \beta_1(R_{M,t} - r_f) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \epsilon_t \qquad (6\text{-}1)$$

where GF_t is the time series value of the green transition factor which is calculated in two versions. The first one is constructing an equally weighted portfolio with a short position in oil and gas companies and a long position in an equally weighted low-carbon power utilities-based portfolio. The second one is constructing the long position with an equally weighted zero-emitters renewable energy portfolio. Returns from each portfolio are explained by the excess return in the market $R_{M,t}$ over the risk-free return, r_f, as well as by size, value, and momentum factors (SMB_t, HML_t, and MOM_t, respectively), while α represents the abnormal return that cannot be explained by the benchmark factors. The coefficients are estimated by linear regression and ϵ_t represents the residual.

Reported results in Table 6-10 demonstrate that only the green factor in North America, based on a long-short portfolio with zero emitters, is able to generate a positive and significant alpha, that represents an excess return of 9.74%. Note that the outperformance of the green factor portfolios with zero emitters is outlined in Table 6-1. While the green factor portfolios with zero emitters do not outperform in the estimated slope coefficient, they do outperform their low carbon intensity counterpart in terms of the alpha. Another relevant finding is the statistically significant negative sign of the market factor in all portfolios, except the European green factor based on zero carbon intensity where is positive, which suggests that the green factor in all other portfolios provides a hedge against downturn market movements.

We can describe the "equity green premium" or "equity greenium" as a measure of the added value of environmentally friendly activities ("green") in terms of market excess returns, as it captures the difference in expected returns on green versus brown stocks. Based on our proxy to measure the carbon transition risk, which is defined as the carbon emissions intensity, our results imply that companies in North America that have completed their transition to producing energy with zero carbon intensity obtain excess market returns when compared with high carbon intensity energy firms.

Our findings provide additional evidence to the literature stream that supports a positive equity greenium in the stock market, which in our case is reflected in the North American energy sector.

Table 6-10

Long-short portfolios with short polluting oil and gas corporations and long low (or zero) carbon intensity

	Green factor based on lower carbon intensity				Green factor based on zero carbon intensity			
	North America		Europe		North America		Europe	
		t stats		t stats		t stats		t stats
Alpha	0.0624	1.51	-0.0123	-0.44	0.0974**	**2.42**	0.0384	1.21
MKT	*-0.5468*	-14.73	*-0.2011*	-6.24	*-0.3657*	-10.11	0.1389	3.78
SMB	-0.4462	-6.12	0.1673	2.28	0.1706	2.40	0.8105	9.68
HML	-0.1403	-1.91	-0.8002	-10.98	-0.2027	-2.84	-0.6865	-8.26
MOM	0.8621	15.30	0.1915	3.88	0.7160	13.05	0.4439	7.88
Adj.R^2	0.3661		0.2349		0.2588		0.2291	

Note: This table presents results of the green transition factor in North America and Europe in its two versions: a) as a portfolio with a long position in low carbon power utilities and a short position with high polluting oil and gas corporations and b) as a portfolio with a long position in zero emitters renewable energy producers and a short position in high polluting oil and gas corporations. The latter portfolio in North America generates a positive and significant alpha that cannot be explained by the Carhart (1997) four-factor model including MKT (market excess return over the risk-free return), SMB (small minus big), HML (high minus low), and MOM (winners minus losers) factors. The t-statistics are based on Newey-West (1987) standard errors and the ** asterisks for alpha denote statistical significance at the 5% level.

7 DISCUSSION:

In order to find empirical evidence of carbon transition risk explaining the stock returns of energy firms, we proposed and extended the Carhart (1997) four-factor model that introduces a new green factor. Our empirical results for the North American and European markets show that the proposed green factor has a negative and significant effect in explaining the returns of high carbon intensity energy firms, represented by oil and gas corporations, and at the same time a positive and significant effect in explaining the returns of companies in the utility sector.

Our findings are particularly strong for green factors constructed with zero emitters. Specifically, we demonstrate that for the case of North America, long-short portfolios based on a long with zero emitters renewable energy producers and short in oil and gas companies generate an excess return as measured by a positive and significant alpha that cannot be explained by the Carhart (1997) four-factor model.

To interpret our findings we analyse the framework under which investors may estimate the impacts of the low carbon transition in the energy companies and how this can influence their share price. This allows us to elaborate on the implications that transition risk exerts on corporate performance.

A simple way in which investors value stocks is by using the discounted cash-flow method according to the relationship established under the Gordon Model (see Gordon 1962):[39]

Formula 7-1

$$p_{rice_{t=0}} \sum_{t=1}^{\infty} \frac{E(Cashflow_t)}{(1+Discount\ rate_t)^t} \qquad (7\text{-}1)$$

[39] Gordon, Myron J. *The investment, financing, and valuation of the corporation*. RD Irwin, 1962.

where the price of the stock today is equal to the expectations and expected cash flows, which are discounted at an appropriate rate that reflects the stock systemic (or systematic) risk; that is, the market risk shared by the rest of the market. The discount rate is also referred to as the cost of the company´s equity capital and is equivalent to the expected return on the stock.

The traditional Capital Asset Pricing Model theory (Sharpe, 1964) argues that only systematic risk should be incorporated into asset prices and derive a risk premium. The idiosyncratic risk is considered under a different line of literature (see Malkiel and Xu 2002 and Bali et al. 2005), which assumes that i) not all investors can hold the market portfolio and fully diversify their risk exposures and that ii) investors fail to deliberately structure their portfolios to accept additional specific risk to obtain extraordinary returns.

Since our analysis focuses on the oil and gas and utilities sector, we do not decide ex-ante whether carbon transition risk arises as a systematic risk factor or an idiosyncratic risk factor.

In an in-depth analysis of climate risk and portfolio management, Sauer and Wellington (2005) follow portfolio theory to split this risk into two constituents: systematic and unsystematic risks. They note that climate risk poses both of these risks.

Other authors however classify climate risk as systematic, as it is considered a macro concern such as overall economic and market risks. This line of literature argues that policies directed to fight against climate change will generate systematic risk across the economy as a whole, impacting energy prices, national income, health, and agriculture, and having a disproportionate effect on energy production and consumption. Unsystematic climate risk, on the other hand, pertains to the specific investment risks associated with particular industries, such as physical and regulatory risks, as well as company-specific risks, including litigation, reputation, and competitiveness risks.

Based on the above, and focusing on the way in which carbon transition risk may affect oil and gas companies, investors may have two ways to incorporate their expectations and estimate their share price through any of the cash flow effect and the discount factor effect.

7.1. The cash flow effect

This relates to the assessment of the impact on the numerator of equation (7-1). This can have different effects across companies within the industry. Moody´s highlighted in a report in 2021 that the material exposure on cash flows of all integrated oil and gas companies due to the energy transition could be very significant (Moody´s, 2021). They underlined four main exposures of concern: (i) the current business profile towards low-carbon transition (ii) the medium-term exposure to policy, technology and market risks (iii) the medium-term response activities, and (iv) the long-term exposure to a fast transition scenario. Investors will therefore incorporate their expectations about lower expected cashflows as follows:

- lower demand for oil and gas over time due to policy initiatives such as the introduction of higher carbon taxes, a reduced trend of carbon emission allowances, or increased investments committed for the energy transition
- the possibility that oil and gas reserves become stranded assets, given the efforts to cut GHG emissions, means zero future cash flows
- changing consumer preferences towards the use of energy
- disruptive technological shocks, as in the power and auto sectors
- the impact on their reputation

This view has been addressed by the academic literature. Atanasova & Schwartz, (2019) perform a panel analysis with firm-level data of Canadian energy corporates and demonstrate that there is a negative effect of increasing investments in underdeveloped reserves on firm value and that the impact is even higher when firm investments are located in countries with strict climate policies.

Here we contend that investors may counterbalance the expected negative impact when translated onto their customers if the oil and gas companies in transition earn positive cash flows from clean energy activities that partially offset the losses resulting from their conventional fossil fuel assets.

7.2. The discount factor effect

Given the uncertainty and/or the speed of these cash flow effects over time, investors may decide instead to discount at a higher rate expected cash flows that are more sensitive to energy transition than less sensitive cash flows. This means that if investors increase the discount rate in the denominator reflecting the higher "carbon transition risk", with the same expected cash flows in the numerator of equation 7-1, they expect a lower share price today.

This increase in the discount rate may be identified as the **"**carbon transition risk premium", and it is equivalent to the additional return investors may require and expect to earn by investing in higher-risk companies. If investors require a "negative premium" in companies involving carbon transition risk, this means that they expect to earn lower returns in the future, but they expect a higher share price today.

A material difference for investors happens whether, for instance, climate change policies impact future cash flows (the numerator) or the discount rate (the denominator). Robeco (2022) points out that when affecting the numerator, the expected returns for average investors remain the same; they cannot benefit from the carbon risk premium unless they have better information about their impact that can enable them to earn higher returns than the rest of the market. Nevertheless, if investors´ actions have the effect of increasing the discount rate due to the uncertainty about climate mitigation policies, which means their expected share prices today are lower, albeit they expect to earn higher returns in the future, then the cost of equity capital of companies subject to such risk is higher.

When we analyse the realised returns that investors receive ex-post, this means that could either result from the cost of the capital-equity channel or the cash flow channel.

However, the expected returns that investors had when they bought a stock are unknown. If investors can accurately assess the exposure of firms to carbon transition risk in their return expectations beforehand, then their anticipated returns could serve as a reliable indicator of realised returns. As investors seek to hedge against this risk, we can estimate in the cross-section of stock returns the resulting carbon transition risk premium.

Bolton and Kacperczyk (2021b) acknowledge the challenge of selecting an asset pricing model that accounts for climate change risk, as no such model has been developed. With this argument, the authors do not adopt a risk-factor approach or examine whether there is a “carbon excess return” or any carbon-transition risk mispricing. However, their findings show that stocks of companies with greater total carbon emissions and changes in emissions generate higher returns, and therefore a positive carbon premium.

The rationale of Pástor et al. (2022)’s model is that despite the fact that green stocks are expected to have lower returns, given that they provide a hedge against climate risks, they could nevertheless outperform brown stocks if there is an expected shift in consumers' or investors' preference changes. Under this process, these unanticipated changes in consumer or investor preferences could explain the positive unexpected returns reported in this thesis. We note that this may arise by (i) changing the cash flows through the consumer channel; (ii) changing the discount rate through the investor channel; or both. This shift in investors’ preferences for green assets could lead to an increase in the cost of equity capital for brown firms.

Our empirical work does not provide conclusive evidence of investors' choices. However, our results are consistent with Pastor et al. (2022) in that there is a higher cost of capital for oil and gas as a result of a shift in investors' preferences for cleaner energy companies (low carbon power utilities and renewable companies). Bolton and Kacperczyk (2021b) also suggest that the discount rate channel is an important factor. They do however argue from a different perspective evidenced by the positive carbon premium of brown companies. This background is also consistent with the fact that if we identify the cost of equity capital with the return on investments (IRR) from the top oil and gas and renewable projects, we can affirm that the IRR delivered by the oil and gas projects is significantly higher than the renewable ones, and therefore their cost of equity capital (Goldman Sachs, 2022b).

Now, we change our focus to discuss the implications for energy companies. The Oil and Gas Climate Initiative, the organisation that groups the largest oil and gas companies in the world to respond to climate change, emphasises that the sector has only very recently, in December 2019, started to announce its commitments to reach net zero emissions by 2050, with intermediate plans and strategies to achieve their emission reduction targets. [40]

Further evidence of the different decarbonisation speeds between oil and gas companies and their cleaner energy counterparts is the capital allocation to clean energy businesses. The IEA (2020) provides evidence that less than 1% of total capital expenditures of oil and gas companies analysed in 2019 has been allocated outside their core business, which is in renewables, carbon capture, use, and storage (CCUS), low carbon liquid and gas projects (hydrogen, biorefineries, biogas) or electric mobility. Nevertheless, looking ahead, a growing number of companies have announced plans to step up their capital allocation into a new

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[40] OGCI Spanish member company Repsol announced in December 2019 its aim to achieve by 2050 net zero emissions, being the first oil and gas company that assumes this target worldwide. Available at https://www.ogci.com/repsol-is-the-first-oil-and-gas-company-to-commit-to-become-a-net-zero-emissions-company-by-2050/

cleaner energy business in the coming years, which could reach up to 30% based on the companies' strategic plans.

Therefore, there is still a very limited time frame in which to close the gap between commitments and delivery to be able to extract long-term market implications to differentiate oil and gas companies with high or low carbon intensity. For this reason, based on our results, if the stock market provides higher returns to renewable energy producers and power utility companies that started to decarbonise their generation business well before oil and gas companies began to invest in cleaner energy technologies, we argue that as long as oil and gas companies differentiate each other's by their lower carbon intensity level, they would be rewarded with higher stock returns and could compete in stock returns with their renewable and power utility counterparts.

Our argument is consistent with the low-carbon premium evidenced by Bernardini et al. (2021) among the European power utilities. Since 2012, the market has recognised and priced in the lower risks associated with companies that have a greater proportion of low-emission greenhouse gas plants in their energy mix. Thus, an investment strategy focused on low-carbon power utility stocks showed higher returns, without altering the overall risk profile.

The possibility of current market inefficiency in pricing climate risk and the certain controversy about the sign and significance of the carbon risk premium creates an opportunity to further develop the research gap. Our findings are focused on a particular albeit relevant section of the market, the energy sector, and are based on the construction of the green factor with a long-short portfolio with positions on low carbon intensity power utilities and high carbon intensity oil and gas companies, respectively. An alternative green factor is constructed with zero-carbon emitters from renewable energy producers on the long side. Furthermore, we analysed a limited period (2014-2020) in North America and Europe and introduce a novel proxy for carbon transition risk, the carbon intensity that can measure the emissions produced per unit of energy generated.

Divergences found in the current literature may be explained by differences in a) cross-section features of the samples chosen (sectors, geographical location), b) time periods considered, c) method used for construction of the green factor portfolio, d) metrics used to measure carbon transition risk.

8 CONCLUSIONS

Over the last few years, there has been growing evidence that climate-related risks are an essential part of the agendas of policymakers, investors, and corporations.

It is well known across academic policy and market circles that GHG emissions must be reduced to stabilise the climate under the remaining "carbon budget" to limit global warming to 1.5ºC (IPCC, 2021). However, the global picture is that the world is not reducing emissions at the required speed, or with the necessary commitment. By the end of 2021, countries that represent more than 80% of global GDP and 77% of global GHG had set net zero emissions targets. Nevertheless, when we consider only strong commitments and clear plans, evidenced by their incorporation in law, these figures represent only 10% of global GDP and 5% of global emissions. Reaching net zero CO_2 emissions by 2050 would require a decrease of approximately 1.4 Gigatons CO_2 each year, almost comparable to the COVID-related 2020 fall, without sacrificing economic growth.

The transition to a lower-carbon economy is a necessary but also a complex pathway that requires a transformation of multiple sectors and consumer behaviours. The transformation of the energy sector is particularly essential when we realise that it has been the single largest contributor to global GHG emissions for the last 30 years and represents roughly one-third of total emissions (IPCC, 2022).

Energy companies are involved in a complex scenario as their net zero emissions commitments need to be compatible with the security of supply and affordability of the energy sources. Investors and energy companies are also facing a dilemma in their investment decision process as their expected financial returns, partly fuelled by their dividend payouts and share buy-backs, are higher than those delivered by the market average and, while the transition to lower-carbon energy businesses can certainly be profitable, their returns are generally lower than for hydrocarbons.

Once we recognise that a change of mindset is needed, we wonder whether financial markets have already incorporated a transition risk to a lower-carbon economy in the valuation of energy companies as a new kind of financial risk. We formulate this question as our first null hypothesis, as to whether financial markets are pricing this risk and reflecting it in a higher share price return of oil and gas companies when compared with other cleaner energy companies (low carbon power utilities and renewable energy producers). Our alternative hypothesis is that financial markets may be reflecting a preference for cleaner energy stocks and rewarding them with a higher share return, while carbon transition risk, in turn, is reflected in a higher cost of equity capital for oil and gas companies.

To support our empirical results in Europe and North America (USA and Canada), we constructed a proxy for carbon transition risk at the firm level with their carbon intensity levels in terms of CO_2 equivalent emissions per energy produced. This proxy is consistent with the public indicator used by energy companies to release their net zero emissions targets and with the required homogeneous measure to compare companies within the same sector. Our scope and methodology follow the Science-based Target initiative (SBTi) guidance, the Greenhouse Gas Protocol to accounting standards for companies, the International Energy Agency (IEA) to establish its benchmarks and targets, and the Transition Pathway Initiative (TPI) database that we selected to make the figures homogenous. This means the scope followed for oil and gas companies is not just direct emissions, but also indirect emissions concentrated in their value chain (Scope 1, 2, and 3 criteria), while for power utility companies the scope is only from electricity generation.

To measure whether stock returns reflect investors´ concerns about carbon transition, we constructed a green factor for the energy sector based on long-short positions with low-high carbon emissions intensity, respectively. The high carbon intensity portfolio is represented by the oil and gas companies and the low carbon intensity portfolio by the selection of low carbon power utility companies in an equally weighted portfolio. A subsequent portfolio of zero-carbon intensity is represented by renewable energy producers.

Our findings reveal that during the sample period between 2014-2020, the green factor had a negative and statistically significant effect on share returns in the energy sector in Europe and North America, and also unveil different patterns of return characteristics in both markets. This suggests that there is a negative effect on the profitability of the energy portfolio, mainly represented by oil and gas companies, while the green factor is positive and significant, explaining the share return of the utility sector. Carbon transition risk is captured by the coefficient beta of our green factor. Reported betas of the green factor in the North American energy portfolio show higher negative values than those in the European, suggesting a higher sensitivity in this geographic area and that energy companies are being penalised here more. The reflection about the positive betas of the green factor for the utility's portfolio is different. Their absolute value is much lower than that obtained for the energy sector, signalling that the return penalisation for the energy sector is greater than the reward for the utilities. The North American portfolio also shows higher positive beta coefficients than the European.

Financial asset pricing models explain that if investors could correctly identify firms' exposure to a carbon transition risk in their return expectations, on an ex-ante basis, then the higher the expected risk, the higher the expected return should be. Our results conclude with an anomaly, given that investors are shown to achieve higher returns with an investment strategy in cleaner energy companies (low carbon power utilities and renewable companies) and find that shares of such companies that provide better carbon transition hedges have higher expected returns, rather than lower, as the theory explains. In other words, investors with this strategy could have reduced the carbon intensity of their portfolios without sacrificing returns.

Given that our proxy for carbon transition risk is a carbon intensity level measured per energy produced, our results suggest that a greater reliance on lower-carbon energy technologies will have the effect of increasing the expected returns on energy companies.

The existence of the green factor evidences financial market preferences for energy companies with lower carbon intensity levels, and carbon transition is not only perceived as a long-term risk in nature but is also already priced in their share value. This confirms our alternative hypothesis that financial markets are reflecting a preference for green stocks and rewarding them with a higher stock return. Carbon transition risk has been reflected in the lower share value of higher-carbon-intensive energy companies, represented by the oil and gas companies in North America and Europe, thus confirming the existence of a new class of financial risk in the energy sector.

Our findings also demonstrate that our green factor in North America, based on a portfolio long with zero emission renewable energy producers and short in oil and gas companies, generates an alpha or an excess return of 9.74%, that cannot be explained by the Carhart (1997) four-factor model and therefore represents another anomaly. Thus, investors could achieve higher returns with a strategy that provides climate coverage rather than a lower return, as the theory explains. This supports the evidence of a positive equity greenium.

The higher reported betas for the green factor in North America's energy and utilities sectors and the existence of a positive alpha in the North American green factor suggest somewhat surprising, particularly considering the European Union's faster and more extensive adoption of clean energy and their consistent leadership in policy and regulation compared to the USA, as outlined in Chapter 3.2.

In parallel, given the anomaly between a theoretically ex-ante higher risk that is not priced by investors ex-post (not reflecting a higher share value of companies with higher carbon intensity), our results show that lower realised returns by oil and gas companies could either result from investors deciding to discount the expected cash flows at a higher rate (the cost of the capital-equity channel) or lower the expected cash flows (the cash flow channel); or both.

Although we cannot be conclusive on investors' choices, we can argue in line with Pastor et al. (2022) that a shift in investors’ preferences for green assets may result in a higher cost of capital for polluting firms.

Since the stock market is the transmission channel that naturally reflects forward-looking expectations for risks and returns, our findings suggest several contributions for energy companies, investors, and policymakers:

a) In the same way that low-carbon power utility companies and renewable energy producers that started earlier in leading the transition have been rewarded with higher returns, it should be expected that lagging oil and gas companies could also be rewarded by the market when transforming to a lower carbon business mix at a higher speed. Some oil and gas companies already have concrete plans and strategies to reach their net zero emissions targets, while others are still preparing for their transition. Some have begun to diversify their business, divesting their higher-intensive emission assets, or investing in lower-carbon energy activities. Companies setting a credible narrative, accompanied by evidence of delivery, should receive a differentiated and higher market value proposition within the sector.

b) Since energy companies with higher carbon intensity levels are penalised with lower returns and a higher cost of equity capital, strategic allocation priority to capital expenditures in a lower carbon business mix should support the basis for lower equity costs. This result has additional implications for management decisions because energy companies more oriented to lower their carbon intensity levels would be compensated with increases in their firm value. This would also enable companies to secure market access in times of financial turbulence and better conditions to finance their growth.

c) Energy companies have traditionally rewarded their shareholders with a high above-market average remuneration because of their higher business risks. Particularly, energy companies have delivered even higher payouts than utility companies. We suggest that, when investors do not obtain an additional return for their higher business risk as they receive from lower-carbon-intensive energy companies, oil and gas companies have higher incentives to solve their capital allocation dilemma. They should therefore allocate higher capital expenditures to lower carbon business. This may be funded through savings arising from lower payouts, albeit comparable with their lowest carbon-intense power utility and renewable counterparts. This will accelerate their transition and would create more value for their shareholders.

d) If energy companies with higher carbon intensity enter progressively at a higher speed into a lower carbon business mix, this will allow positive signalling to other financial participants such as rating agencies. This will allow a capital allocation with a priority focus on business risk reduction, and a financial policy oriented to fund their lower carbon business growth with higher retained cash flows. Because this requires lower payouts, it will provide solid grounds for higher credit ratings. This may also decrease their weighted cost of capital and secure access to capital markets in better conditions to finance their transition to a lower-carbon business mix.

e) The proposed green factor can be used as a tool to integrate carbon transition risk in multi-asset portfolios to assess how energy companies adapt to decarbonisation and construct portfolios to hedge against this risk. While investors may believe that ex-ante returns may be lower for those companies with lower-carbon energy businesses, our results suggest that the reduction of transition risk in their portfolio may also provide higher returns ex-post.

f) Because of all of the above-mentioned factors, investors may be willing to reward companies that are likely to succeed in their energy transition.

g) Policies oriented to promote capital replacement from fossil fuels to renewable energy sources have demonstrated a positive influence to reduce carbon intensity levels and financial markets have rewarded this with the effect of increasing the expected returns on those companies producing energy with lower carbon intensity levels. Since almost half of the required reductions to achieve net zero emissions in 2050 are dependent on technologies that are still in the demonstration or prototype phase, such as clean hydrogen, bioenergy, and carbon capture, utilisation, and storage (CCUS), it is necessary to continue innovating and developing new technologies (IEA,2021c).

Given that private investments require financial reward, policies to de-risk technological advances would create a virtuous circle without the need to punish fossil fuels with additional carbon taxes or ban their activities, as this is difficult to implement on a global basis. In line with the arguments of Bolton and Kacperczyk (2021b), financial markets will play that role, increasing the cost of equity capital and lowering stock returns, thereby punishing those companies with higher carbon intensity levels.

To the best of our knowledge, there was no existing evidence about the impact of transition risk on the energy sector stock returns. Our results and methodology can be used to assess the effects of carbon transition risk in the energy sector. We contribute to measuring climate-related risks by the sector´s activity, using carbon intensity. This is a measure of firms' total emissions scaled by their energy produced and therefore differs from the metrics based on sales or revenues that are commonly used in the literature.

The inclusion of the proposed green factor improves the explanatory power of the benchmark Carhart (1997) four-factor model. Reported green factor betas for the energy sector are negative and significant while the utility sector shows positive and significant betas under all specifications considered. Our findings are new in the literature and can be exploited to improve carbon transition risk management strategies. Finally, our results suggest that the green factor betas can be used to explain equity performance within the energy sector.

Investment decisions towards low-carbon businesses in companies trying to transform towards multi-energy business models require new valuation models. Additional lines of research could provide insights into the different costs of equity-capital to be allocated to each business, to serve as hurdle-return rates, depending on different green factors.

The method applied to construct the green factor may be further extended to other sectors immersed in the transition to a lower carbon economy such as transportation (automobile, shipping, or airlines), industry (chemicals, steel, cement), or building materials. Likewise, another line of research may identify the relationship between the green factor and carbon pricing mechanisms, such as the European ETS or similar systems in the global markets.

Future lines of research may be developed based on the still limited evidence and certain controversy on the pricing of transition risk in financial markets. Especially relevant would be to analyze the volatility of the green factor over time and at times like the present, in which cash-flow generation and profits of energy companies derived from their fossil fuel businesses exceed expectations.

Most of the literature currently focuses on multiple sectors with a high degree of heterogeneity. An additional focus on sector-based research would help companies, investors, and policymakers to evaluate each sector's adaptation to climate-related risks.

Low-carbon technological innovation is required to reach the net zero target in 2050. The availability of more sector-level data would serve to support capital flows to develop these technologies. Climate sector risk knowledge should be increased to provide access to a broader range of financial institutions and investors, thereby creating more favourable financing conditions.

An in-depth knowledge of how to thrive in the transition into a low-carbon economy will help to bridge the capital allocation gap between energy companies and financial markets and will contribute to joint efforts in the challenging ambition to reach the zero emissions target globally.

References

Alessi, L., Ossola, E., & Panzica, R. (2019). The Greenium matters: Evidence on the Pricing of Climate Risk. *University of Milan Bicocca Department of Economics, Management and Statistics Working Paper*, (418).

Amel-Zadeh, A., & Serafeim, G. (2018). Why and How Investors Use ESG Information: Evidence from a Global Survey. *Financial Analysts Journal*, *74*(3), 87-103.

Atanasova, C., & Schwartz, E. S. (2019). *Stranded fossil fuel reserves and firm value* (No. w26497). National Bureau of Economic Research.

Atz, U., Van Holt, T., Liu, Z. Z., & Bruno, C. C. (2022). Does sustainability generate better financial performance? review, meta-analysis, and propositions. *Journal of Sustainable Finance & Investment*, 1-24.

Avramov, D., Cheng, S., Lioui, A., & Tarelli, A. (2022). Sustainable investing with ESG rating uncertainty. *Journal of Financial Economics*, *145*(2), 642-664.

Ayaydin, O. & Thewissen, J. (2016). The financial reward for environmental performance in the energy sector. *Energy & Environment*, 27, 389-413.

Bali, T. G., Cakici, N., Yan, X., & Zhang, Z. (2005). Does idiosyncratic risk really matter? *The Journal of Finance*, *60*(2), 905-929.

Berg, F., Koelbel, J. F., & Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. *Review of Finance*, *26*(6), 1315-1344.

Bernardini, E., Di Giampaolo, J., Faiella, I., & Poli, R. (2021). The impact of carbon risk on stock returns: evidence from the European electric utilities. *Journal of Sustainable Finance & Investment*, *11*(1), 1-26.

Blitz, D. (2020). Factor Performance 2010-2019: A Lost Decade? *The Journal of Index Investing*, 11 (2), 57-65.

Blitz, D., Hanauer, M.X, Vidojevic, M. & Van Vliet, P. (2018). Five Concerns with the Five-Factor Model. *The Journal of Portfolio Management Quantitative,* 44 (4) 71-78.

BloombergNEF. (2022a). *Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh.* https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/

BloombergNEF.(2022b). *Energy Transition Investment Trends 2022. Tracking global investment in the low-carbon energy transition.* https://assets.bbhub.io/professional/sites/24/Energy-Transition-Investment-Trends-Exec-Summary-2022.pdf

Bolton, P., & Kacperczyk, M. (2021a). Do investors care about carbon risk? *Journal of financial economics*, *142*(2), 517-549.

Bolton, P., & Kacperczyk, M. (2021b). *Global pricing of carbon-transition risk* (No. w28510). National Bureau of Economic Research.

Carbon Tracker. (2021). *Adapt to survive. Why oil and gas companies must plan for net zero and avoid stranded assets.* https://carbontracker.org/reports/adapt-to-survive/

Carhart, M. M. (1997). On Persistence in Mutual Fund Performance. *The Journal of Finance,* 52(1), 57-82.

Castelo, D., Rathmann, R., Soares, B., Frossard, A., Szklo, A., & Schaeffer, R. (2012). A multicriteria approach for measuring the carbon-risk of oil companies. *Energy Strategy Reviews,*1, 122-129.

Cook, J., Oreskes, N., Doran, P. T., Anderegg, W. R., Verheggen, B., Maibach, E. W., ... & Rice, K. (2016). Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. *Environmental research letters*, *11*(4), 048002.

Denton, F.; Wilbanks, T.J.; Abeysinghe, A.C.; Burton, I.; Gao, Q.; Lemos, M.C.; Warner, K. Climate-resilient pathways: Adaptation, mitigation, and sustainable development. In Climate Change 2014: Impacts, Adaptation, and Vulnerability; Cambridge University Press: Cambridge, UK, 2014; pp. 1101–1131

Diaz-Rainey, I., Robertson, B., & Wilson, C. (2017). Stranded research? Leading finance journals are silent on climate change. *Climatic Change*, *143*(1), 243-260.

Eaton, C.. & MacFarlane, S. (2020, December 27). 2020 Was One of the Worst-Ever Years for Oil Write-Downs. *The Wall Street Journal.* https://www.wsj.com/articles/2020-was-one-of-the-worst-ever-years-for-oil-write-downs-11609077600

Edmans, A. (2011). Does the stock market fully value intangibles? Employee satisfaction and equity prices. *Journal of Financial economics*, *101*(3), 621-640.

ESRB. (2016). *Too late, too sudden: Transition to a low-carbon economy and systemic risk. Report of the Advisory Scientific Committee*, 6. Frankfurt, Germany: European Systemic Risk Board.

European Commission. (2020). *Kick-starting the journey towards a climate-neutral Europe by 2050.* https://ec.europa.eu/clima/sites/clima/files/strategies/progress/docs/com_2020_777_en.pdf

Fama, E. & French, K. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33, 3–56.

Fama, E. & French, K. (2015). A Five-Factor Asset Pricing Model. *Journal of Financial Economics,* 116, 1-22.

Financial Times. (2021). *The work that remains to reach net zero.* https://www.ft.com/content/9918f2da-131f-4f2a-81e6-a179a23ce1d0

Gibson Brandon, R., Krueger, P., & Schmidt, P. S. (2021). ESG rating disagreement and stock returns. *Financial Analysts Journal*, *77*(4), 104-127.

Gimeno, R. & González, C. (2022). The role of a green factor on stock prices. When Fama & French go green. Technical report, Banco de España.

Global Carbon Project. (2022). *Global Carbon Budget 2022.* https://www.globalcarbonproject.org/carbonbudget/22/files/GCP_CarbonBudget_2022.pdf

Goldman Sachs. (2021). *The value of ESG: The impact on US sector and stock valuations.* https://publishing.gs.com/content/research/en/reports/2021/01/25/d56d99aa-22a8-4e09-840d-30899fd375c0.html

Goldman Sachs. (2022a). *Strategy Matters: Europe's time for buybacks.* https://publishing.gs.com/content/research/en/reports/2022/06/13/a24884ec-327b-4d30-aaa9-e4efa0b64704.html#

Goldman Sachs. (2022b). *Security of Supply and the Return of Energy Capex*. https://publishing.gs.com/content/research/en/reports/2022/03/17/d771f8b6-c03e-4d06-9ca2-fef0c244a724.html#

Goldman Sachs. (2022c). *Affordability, Security and Innovation.* https://publishing.gs.com/content/research/en/reports/2022/11/03/309c0874-71e9-48e4-8879-55367afb1544.pdf

Görgen, M., Jacob, A., Nerlinger, M., Riordan, R., Rohleder, M., & Wilkens, M. (2020). Carbon risk. *Available at SSRN 2930897*.

Green House Gas Protocol. *Corporate Value Chain (Scope 3) Accounting and Reporting Standard.* https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard-EReader_041613_0.pdf

Halbritter, G., & Dorfleitner, G. (2015). The wages of social responsibility—where are they? A critical review of ESG investing. *Review of Financial Economics*, *26*, 25-35.

Hoepner, A. G., Oikonomou, I., Sautner, Z., Starks, L. T., & Zhou, X. (2018). ESG shareholder engagement and downside risk. Finance Working Paper N° 671/2020

Hsu, P. H., Li, K., & Tsou, C. Y. (2022). The pollution premium. *Journal of Finance, Forthcoming*.

IEA. (2020) The oil and gas industry in energy transitions. https://www.iea.org/reports/the-oil-and-gas-industry-in-energy-transitions

IEA. (2021a) Key world energy statistics https://iea.blob.core.windows.net/assets/52f66a88-0b63-4ad2-94a5-29d36e864b82/KeyWorldEnergyStatistics2021.pdf https://www.iea.org/reports/key-world-energy-statistics-2021/supply

IEA. (2021b) Greenhouse Gas Emissions from Energy Data Explorer. https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer

IEA (2021c) Net Zero by 2050. https://www.iea.org/reports/net-zero-by-2050

IEA. (2022) Global Energy Review: CO2 emissions in 2021. https://iea.blob.core.windows.net/assets/c3086240-732b-4f6a-89d7-db01be018f5e/GlobalEnergyReviewCO2Emissionsin2021.pdf

Ilhan, E., Krueger, P., Sautner, Z., & Starks, L. T. (2021). Climate risk disclosure and institutional investors. *Swiss Finance Institute Research Paper*, (19-66).

Imperial College Business School and IEA (2021). Clean Energy Investing: Global Comparison of Investment Returns.

https://www.imperial.ac.uk/business-school/faculty-research/research-centres/centre-climate-finance-investment/research/clean-energy-investing-global-comparison-investment-returns/

Institute for Energy Economics and Financial Affairs. (2021). *Capital markets are shifting decisively towards cleaner investments.* https://ieefa.org/tag/ishares-global-clean-energy/

IOSCO. (2022). *Report on Sustainability-related Issuer Disclosures.* https://www.iosco.org/library/pubdocs/pdf/IOSCOPD678.pdf

IPCC. (2014) Fifth Assessment Report. https://www.ipcc.ch/assessment-report/ar5/

IPCC. (2020) The concept of risk in the IPCC Sixth Assessment Report: a summary of cross-Working Group discussions

IPCC. (2021) Sixth Assessment Report. Working Group I. https://www.ipcc.ch/report/ar6/wg1/downloads/outreach/IPCC_AR6_WGI_Press_Conference_Slides.pdf

IPCC. (2022) Sixth Assessment Report. Working Group III. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

IPIECA. (2021). *The oil and gas sector and the SDGs. Scope of the map.* https://www.ipieca.org/our-work/sustainability/supporting-the-sdgs/sdg-roadmap/the-oil-and-gas-sector-and-the-sdgs/scope-of-the-roadmap/

IRENA. (2020a). *Renewable power generation costs in 2019.* https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

IRENA. (2020b), *Green Hydrogen Cost Reduction: Scaling up Electrolyzers to Meet the 1,5ºC Climate Goal*, International Renewable Energy Agency. Abu Dhabi. https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction

IRENA. (2022a). *Renewable Energy Statistics, 2022.* https://www.irena.org/publications/2022/Jul/Renewable-Energy-Statistics-2022

IRENA. (2022b). *Renewable Capacity Statistics 2022.* https://irena.org/publications/2022/Apr/Renewable-Capacity-Statistics-2022

IRENA. (2022c). *Renewable Power Generation Costs in 2021*. https://www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021

Jiang, R., & Weng, C. (2019). Climate change risk and agriculture-related stocks. *Available at SSRN 3506311*.

Kacperczyk, M., Van Nieuwerburgh, S., & Veldkamp, L. (2016). A rational theory of mutual funds' attention allocation. Econometrica, 84 (2), 571-626.

Kelemen, R. D., & Vogel, D. (2010). Trading places: The role of the United States and the European Union in international environmental politics. Comparative Political Studies, 43(4), 427-456.

Koch N. & Bassen, A. (2013). Valuing the carbon exposure of European utilities. The role of fuel mix, permit allocation and replacement investments. *Energy Economics* 36, 431–443.

Larcker, D. & Watts, E. (2019). Where is the Greenium? *Journal of Accounting and Economics,* 69, Issues 2–3.

Lee, D. D., Faff, R. W., & Langfield-Smith, K. (2009). Revisiting the vexing question: does superior corporate social performance lead to improved financial performance?. *Australian Journal of Management*, *34*(1), 21-49.

Malkiel, B. G., & Xu, Y. (2002). Idiosyncratic risk and security returns. *University of Texas at Dallas (November 2002).*

Moody´s. (2021). *Integrated Oil and Gas. Global Carbon transition assessments show material exposure for all companies.* https://www.moodys.com/researchdocumentcontentpage.aspx?docid=PBC_1269680

Newey, W. K., & West, K. D. (1987). Hypothesis testing with efficient method of moments estimation. *International Economic Review*, 777-787.

NGFS. (2018). First Progress Report. https://www.ngfs.net/en/first-progress-report

NGFS (2019). A call for action. Climate Change as a source of financial risk, First comprehensive report. https://www.ngfs.net/en/first-comprehensive-report-call-action

Nordhaus, W. D. (1977). Economic growth and climate: the carbon dioxide problem. *The American Economic Review*, *67*(1), 341-346.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, *109*(6), 1991-2014.

NRGI. (2021). *Risky Bet. National Oil Companies in the Energy Transition.* https://resourcegovernance.org/sites/default/files/documents/risky-bet-national-oil-companies-in-the-energy-transition-summary.pdf

Oberndorfer, U. (2009). EU emission allowances and the stock market: evidence from the electricity industry. *Ecological Economics*, 68, 1116–1129.

Oestreich, A.M. & Tsiakas, I. (2015). Carbon emissions and stock returns: Evidence from the EU Emissions Trading Scheme. *Journal of Banking & Finance*, 58, 294-308.

Parker, C. F., & Karlsson, C. (2018). The UN climate change negotiations and the role of the United States: assessing American leadership from Copenhagen to Paris. *Environmental Politics*, *27*(3), 519-540.

Pástor, Ľ., Stambaugh, R. F., & Taylor, L. A. (2021). Sustainable investing in equilibrium. *Journal of Financial Economics*, *142*(2), 550-571.

Pástor, Ľ., Stambaugh, R. F., & Taylor, L. A. (2022). Dissecting green returns. *Journal of Financial Economics*, *146*(2), 403-424.

Pätäri, S., Arminen, H., Tuppura, A. & Jantunen, A. (2014). Competitive and responsible? The relationship between corporate social and financial performance in the energy sector, *Renewable and Sustainable Energy Reviews*, 37, 142-154.

Petersen, M. A. (2009). Estimating standard errors in finance panel data sets: Comparing approaches. *The Review of financial studies*, *22*(1), 435-480.

Rayner, T., & Jordan, A. (2016). Climate change policy in the European Union. In *Oxford research encyclopedia of climate science*.

Reisinger, A., Howden, M., Vera, C., Garschagen, M., Hurlbert, M., Kreibiehl, S.& Ranasinghe, R. (2020). The concept of risk in the IPCC Sixth Assessment Report: A summary of cross-working group discussions. *Intergovernmental Panel on Climate Change*, 15.

Robeco. (2022). *Expected returns 2022-2026.* https://www.robeco.com/docm/docu-5yer-the-roasting-twenties-2022-2026-en.pdf

Rowlands, I. H. (2000), *Beauty and the beast? BP's and Exxon's positions on global climate change,* Environment and Planning C: Government and Policy, 18: 3, 339–54.

Sauer, A., & Wellington, F. (2005). Framing Climate Risk in Portfolio Management. *World Resources Institute–CERES: Boston, MA.*

SBTi. (2020). *Guidance on setting science-based targets for Oil, Gas and Integrated Energy companies.* https://sciencebasedtargets.org/resources/legacy/2020/08/OG-Guidance.pdf

Seltzer, L. H., Starks, L., & Zhu, Q. (2022). *Climate regulatory risk and corporate bonds* (No. w29994). National Bureau of Economic Research.

Semieniuk, G., Campiglio, E., Mercure, J. F., Volz, U., & Edwards, N. R. (2021). Low-carbon transition risks for finance. *Wiley Interdisciplinary Reviews: Climate Change*, *12*(1), e678.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *The journal of finance*, *19*(3), 425-442.

Shaw, F. & Donovan, C. (2019). Assessing the Preparedness of Major Oil and Gas Companies for a Low-Carbon Energy Transition. *SSRN Electronic Journal.*

Skodvin, T., & Skjaerseth, J. (2003). *Climate change and the oil industry: Common problem, different strategies*. Manchester University Press.

TCFD. (2017). *Recommendations of the task force on climate-related financial disclosures.* Task Force on Climate-related Financial Disclosures. https://www.fsb-tcfd.org/recommendations/

Thywissen, K. Components of Risk: A Comparative Glossary (Studies of the University: Research, Counsel, Education); UNU Institute for Environment and Human Security: Bonn, Germany, 2006. [14,15]

TPI. (2021a). *Carbon Performance assessment of oil & gas producers: note on methodology*. https://www.transitionpathwayinitiative.org/publications/96.pdf?type=Publication

TPI (2021b). *Carbon Performance assessment of electricity utilities: note on methodology.* https://www.transitionpathwayinitiative.org/publications/94.pdf?type=Publication

UNCTAD. (2020). *Impact of the COVID-19 Pandemic on Trade and Development: Transitioning to a New Normal.* https://unctad.org/publication/impact-covid-19-pandemic-trade-and-development-lessons-learned

Veith, S., Werner J.R. & Zimmermann J. (2009). Capital market response to emission rights returns: Evidence from the European power sector. *Energy Economics*, 31, 605-613.

Venturini, A. (2022). Climate change, risk factors and stock returns: A review of the literature. *International Review of Financial Analysis*, *79*, 101934.

Weart, S. (2013). Rise of interdisciplinary research on climate. *Proceedings of the National Academy of Sciences*, *110*(supplement_1), 3657-3664.

World Economic Forum. (2021). *Global Risks Report 2021* https://www.weforum.org/reports/the-global-risks-report-2021

World Economic Forum. (2022). *Global Risks Report 2022* https://www.weforum.org/reports/global-risks-report-2022

Yergin, D., & Pravettoni, E. (2016). Do Investments in Oil and Gas Constitute ‘Systemic Risk’? *IHS Markit Systemic Risk Strategic Report, October.*

Appendices

Appendix A- Detail of the portfolios and their constituents

North American oil and gas companies: (number = 25)

Company Name	Country	Portfolio	ISIN
Canadian Natural Resources	Canada	Oil & Gas	CA1363851017
Cenovus Energy	Canada	Oil & Gas	CA15135U1093
Imperial Oil	Canada	Oil & Gas	CA4530384086
Ovintiv	Canada	Oil & Gas	US69047Q1022
Suncor Energy	Canada	Oil & Gas	CA8672241079
APA Corporation	USA	Oil & Gas	US03743Q1085
Anadarko Petroleum	USA	Oil & Gas	US0325111070
Andeavor	USA	Oil & Gas	US03349M1053
Cabot Oil & Gas	USA	Oil & Gas	US1270971039
Chevron	USA	Oil & Gas	US1667641005
Concho Resources	USA	Oil & Gas	US20605P1012
ConocoPhillips	USA	Oil & Gas	US20825C1045
Devon Energy	USA	Oil & Gas	US25179M1036
Diamondback Energy	USA	Oil & Gas	US25278X1090
EOG Resources	USA	Oil & Gas	US26875P1012
Exxon Mobil	USA	Oil & Gas	US30231G1022
Hess	USA	Oil & Gas	US42809H1077
HollyFrontier	USA	Oil & Gas	US4361061082
Marathon Oil	USA	Oil & Gas	US5658491064
Marathon Petroleum	USA	Oil & Gas	US56585A1025
Noble Energy	USA	Oil & Gas	US6550441058
Occidental Petroleum	USA	Oil & Gas	US6745991058
Phillips 66	USA	Oil & Gas	US7185461040
Pioneer Natural Resources	USA	Oil & Gas	US7237871071
Valero Energy	USA	Oil & Gas	US91913Y1001

European oil and gas companies: (number = 10)

Company Name	Country	Portfolio	ISIN
OMV	Austria	Oil & Gas	AT0000743059
Neste	Finland	Oil & Gas	FI0009013296
TotalEnergies	France	Oil & Gas	FR0000120271
Eni	Italy	Oil & Gas	IT0003132476
Equinor	Norway	Oil & Gas	NO0010096985
Galp Energia	Portugal	Oil & Gas	PTGAL0AM0009
Repsol	Spain	Oil & Gas	ES0173516115
Lundin Energy	Sweden	Oil & Gas	SE0000825820
BP	UK	Oil & Gas	GB0007980591
Royal Dutch Shell	UK	Oil & Gas	GB00B03MM408, GB00B03MLX29

North American power utility companies: (number = 39)

Company Name	Country	Porfolio	ISIN
lgonquin Power & Utilities	Canada	Power Utility	CA0158571053
Emera	Canada	Power Utility	CA2908761018
Fortis	Canada	Power Utility	CA3495531079
Hydro One	Canada	Power Utility	CA4488112083
AES	USA	Power Utility	US00130H1059
Alliant Energy	USA	Power Utility	US0188021085
Ameren	USA	Power Utility	US0236081024
American Electric Power	USA	Power Utility	US0255371017
Berkshire Hathaway Power	USA	Power Utility	US0846701086, US0846707026
Black Hills	USA	Power Utility	US0921131092
CMS Energy	USA	Power Utility	US1258961002
CenterPoint Energy	USA	Power Utility	US15189T1079
Con Edison	USA	Power Utility	US2091151041
DTE Energy	USA	Power Utility	US2333311072
Dominion Energy	USA	Power Utility	US25746U1097
Duke Energy	USA	Power Utility	US26441C2044
Edison International	USA	Power Utility	US2810201077
Entergy	USA	Power Utility	US29364G1031
Evergy	USA	Power Utility	US30034W1062
Eversource Energy	USA	Power Utility	US30040W1080
Exelon	USA	Power Utility	US30161N1019
Firstenergy	USA	Power Utility	US3379321074
Hawaiian Electric	USA	Power Utility	US4198701009
Idacorp	USA	Power Utility	US4511071064
NRG Energy	USA	Power Utility	US6293775085
NextEra Energy	USA	Power Utility	US65339F1012
NiSource	USA	Power Utility	US65473P1057
OGE Energy	USA	Power Utility	US6708371033
PG&E	USA	Power Utility	US69331C1080

PPL	USA	Power Utility	US69351T1060
Pinnacle West Capital	USA	Power Utility	US7234841010
Portland General Electric	USA	Power Utility	US7365088472
Public Service Enterprise	USA	Power Utility	US7445731067
Sempra Energy	USA	Power Utility	US8168511090
Southern Company	USA	Power Utility	US8425871071
Vectren	USA	Power Utility	US92240G1013
Vistra Energy	USA	Power Utility	US92840M1027
WEC Energy Group	USA	Power Utility	US92939U1060
XCEL Energy	USA	Power Utility	US98389B1008

European power utility companies: (number = 21)

Company Name	**Country**	**Portfolio**	**ISIN**
Verbund AG	Austria	Power Utility	AT0000746409
Elia Group	Belgium	Power Utility	BE0003822393
CEZ	Czechia	Power Utility	CZ0005112300
Orsted	Denmark	Power Utility	DK0060094928
Fortum	Finland	Power Utility	FI0009007132
EDF	France	Power Utility	FR0010242511
Engie	France	Power Utility	FR0010208488
E.ON	Germany	Power Utility	DE000ENAG999
Enbw Energie	Germany	Power Utility	DE0005220008
Innogy	Germany	Power Utility	DE000A2AADD2
RWE	Germany	Power Utility	DE0007037129, DE0007037145
Uniper	Germany	Power Utility	DE000UNSE018
Enel	Italy	Power Utility	IT0003128367
Terna	Italy	Power Utility	IT0003242622
PGE	Poland	Power Utility	PLPGER000010
EDP	Portugal	Power Utility	PTEDP0AM0009
Endesa	Spain	Power Utility	ES0130670112
Iberdrola	Spain	Power Utility	ES0144580Y14
Red Electrica	Spain	Power Utility	ES0173093024
National Grid	UK	Power Utility	GB00BDR05C01
SSE	UK	Power Utility	GB0007908733

North American renewable energy producers (zero emitters): (number =16)

Company Name	Country	Portfolio	ISIN
Anaergia	Canada	Renewable	CA03253E1079
Boralex	Canada	Renewable	CA09950M3003
Brookfield Renewable	Canada	Renewable	BMG162581083
Innergex Renewable	Canada	Renewable	CA45790B1040
Northland Power	Canada	Renewable	CA6665111002
Polaris Infraestructure	Canada	Renewable	CA73106R1001
Transalta Renewable	Canada	Renewable	CA8934631091
Altus Power	USA	Renewable	US02217A1025
ATN International	USA	Renewable	US00215F1075
Avangrid Inc	USA	Renewable	US05351W1036
Clearway Energy	USA	Renewable	US18539C1053
FTC Solar Inc	USA	Renewable	US30320C1036
Montauk Renewable	USA	Renewable	US61218C1036
NextEra Energy Partners	USA	Renewable	US65341B1061
Ormat Technologies	USA	Renewable	US6866881021
Renesola Ltd-ADR	USA	Renewable	US75971T3014

European renewable energy producers (zero emitters): (number =33)

Company Name	Country	Portfolio	ISIN
Enefit Green AS	Estonia	Renewable	EE3100137985
UPM-Kymmene OYJ	Finland	Renewable	FI0009005987
Albioma SA	France	Renewable	FR0000060402
Neoen SA	France	Renewable	FR0011675362
Voltalia SA	France	Renewable	FR0011995588
BayWa AG	Germany	Renewable	DE0005194062
Energiekontor AG	Germany	Renewable	DE0005313506
Encavis AG	Germany	Renewable	DE0006095003
PNE AG	Germany	Renewable	DE000A0JBPG2
Envitec Biogas	Germany	Renewable	DE000A0MVLS8
7C Solarparken AG	Germany	Renewable	DE000A11QW68
Friedrich Vorwer	Germany	Renewable	DE000A255F11
GEK Terna Holdings	Greece	Renewable	GRS145003000
Terna Energy SA	Greece	Renewable	GRS496003005
ERG SPA	Italy	Renewable	IT0001157020
Falck Renewables	Italy	Renewable	IT0003198790
Alerion	Italy	Renewable	IT0004720733
Atlantica	UK	Renewable	GB00BLP5YB54
Bonheur ASA	Norway	Renewable	NO0003110603
Arendals Fosseko	Norway	Renewable	NO0003572802
Scatec ASA	Norway	Renewable	NO0010715139
Otovo ASA	Norway	Renewable	NO0010809783
Polenergia SA	Poland	Renewable	PLPLSEP00013
Greenvolt-Energias Renovaveis	Portugal	Renewable	PTGNV0AM0001

Greenalia SA	Spain	Renewable	ES0105293007
Holaluz-Clidom SA	Spain	Renewable	ES0105456026
Enerside Energy	Spain	Renewable	ES0105634002
Acciona SA	Spain	Renewable	ES0125220311
EDP Renovaveis SA	Spain	Renewable	ES0127797019
Solaria Energia	Spain	Renewable	ES0165386014
Holmen AB	Sweden	Renewable	SE0011090018
Aventron AG	Switzerland	Renewable	CH0023777235
Romande Energie	Switzerland	Renewable	CH0025607331