Measuring the impact of carbon transition risk in the equity performance of energy corporations

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Abstract

Energy corporates are heavily exposed to carbon-transition risk as the global system fights to transform the economy from fossil fuels to green energy. We construct a green factor capturing the carbon transition risk premium for the energy related sector based on long-short positions with high versus low polluting corporations within the oil and gas and utilities sectors. While highly polluting companies are identified from the oil and gas sectors, low polluting companies are selected from power utilities based on low-carbon technologies and zero-carbon emitters from renewable energy producers. A carbon intensity measure from Transition Pathway Initiative (TPI) data for North America and Europe is used for this purpose. We find that the green factor delivers positive risk adjusted returns in both geographical areas considered. We also explore the effect of the green factor in explaining returns and find that a) it has a negative and significant effect in explaining returns of the energy sector, including oil and gas corporations b) it exerts a positive and significant effect in explaining returns in the utility sector. An alternative green factor constructed with zero-carbon emitters from renewable energy producers. Reported results show that this contributes to the explanation of returns and delivers a positive alpha. Our findings collaborate the view that investments in low emitting technologies provide a hedge of carbon transition risk.

JEL classifications: G12, G14, G-32

Key words: transition risk, oil and gas, utilities, green investing, zero emissions

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1. Introduction

The engagement of market participants and policy makers on climate change has become evident over the past two decades. The “energy transition” from hydrocarbons to renewables and electrification is a leading policy and academic debates. As highlighted by Bolton (2021b) the aftermath of the COVID pandemic more than 100 countries committed to carbon neutrality targets that represented 50% of world GDP. The recent invasion of Ukraine has increased the commitment to the energy transition with Europe and the United States adopting massive green initiatives (RePowerEU Inflation Reduction Act). In the EU policy makers have escalated ambitions to rollout renewable power and green hydrogen projects across the block as means of accelerating the energy transition while increasing energy security by replacing dependence on Russian fossil fuels. Across the Atlantic the recently introduced $370 bn package on green subsides representing the greatest package for energy transition by any country.[4]

Under this transformative paradigm oil and gas companies are facing a critical challenge as the world embraces the net zero commitments. While it is clear that fossil fuels remain the main drivers of near-term returns, failure to address growing calls to reduce greenhouse gas emissions will threaten their long-term performance and acceptability.

In this paper we analyse the implications of the transition to a lower-carbon economy by capturing the key characteristics of the Oil, Gas and power sectors. The purpose is to measure the exposure of investors to transition risk by quantifying the extent to which the adaptation to the climate goals is priced as a long-term premium affecting corporate performance in the Oil and Gas and the power sectors. Our work deepens the understanding of the effects of carbon transition risk by looking at stock prices of global energy and power utility corporations with highly different adjustments towards carbon neutrality. Acknowledging carbon transition risk is a global challenge as demonstrated by the recent literature. As underlined by Bolton and Kacperczyk (2021b) transition risk is the amalgamation of a wide range of shocks including transition to cleaner energy and carbon neutrality.

We focus on the impact of transition risk on the financial performance of the main oil and gas listed companies in Europe and North America, given their significant contribution to greenhouse gas 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 their corporate performance. Carbon transition risk represents the uncertain rate of adjustment towards carbon neutrality. This paper therefore sheds light on to the literature of the energy transition which represents a global challenge that requires coordinated direction and a common course of action. In the words of Dr. Fatih Birol, IEA Executive Director “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. ”[5]

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[4] See FT article “Rush for US Energy clean energy subsidies boots brokers and lawyers.” 13th of February 2023

[5] Full report available at https://www.iea.org/reports/the-oil-and-gas-industry-in-energy-transitions

Our results have important implication for institutional investors that have a significant exposure to equity and debt of North American and European oil and gas corporations as well as power utilities. Transition risk is important to regulators and supervisory authorities.

Our purpose is to analyse the extent to which financial markets are already pricing carbon transition risk in the oil and gas sector. This is expected to be reflected in higher stock returns and increased cost of equity capital in the energy sector as a whole. We alternatively address whether financial markets are reflecting a preference for green stocks and rewarding them with a higher stock return for a carbon transition risk.

The first hypothesis is consistent with the predictions of the equilibrium model of Pastor et al. (2021) which establishes that green assets will have lower expected returns than brown because green assets act as hedges of climate risk. According to this model green assets outperform when positive shocks affect the sustainability factor in a way that it captures a shift of customer preferences towards green assets. This process is partly driven due to change in regulation enhancing the green transition. Greener assets that offer lower expected returns therefore reflect a lower risk premium. When green assets deliver a positive expected return reflect a preference premium. This later hypothesis will be consistent with the finding of lower realized returns for the oil and gas sectors as preference for brown assets decrease.

There is an ample consensus in the academic literature and practitioner community regarding the division of climate-related risks, between 'physical risk' and 'transition risk'. The term 'physical risk' is closely related to risks arising from climate change impacts and climate-related hazards, while the term 'transition risk' typically refers to risks associated with the transition to a low carbon economy. Our approach requires the introduction of a green transition factor to be used for the energy sector and power utilities. The factor is constructed using long-short positions under two approaches. We first take long positions in low emissions power utility corporates and short positions in carbon intensive oil and gas corporates with high emissions; our second method takes zero emissions renewable energy producers in the long side. This allows us to address the impact of carbon transition risk affecting the energy and power utility sectors, which are represented in this analysis by the largest oil and gas and power firms in the developed economies of Europe and North America. By measuring the effect of carbon transition risks on the risk-return profile for shareholders we can address the consequent impact on the cost of equity of these corporations as well as shedding light on the impact of new technologies in oil and gas companies.

Our work is conducted for the European and North American case separately and focuses on those companies within the oil and gas and the power-utility sector for which there is data on emissions intensity as recorded by Transition Pathway Initiative (TPI). The metric used for capturing emissions at corporate level in this paper is a novel feature. The academic literature has mainly applied two approaches. The first uses data based on global carbon emission levels defined as the percentage changes in emissions. The second is based on a carbon intensity index metric. This requires defining emissions as in relation to revenues to avoid size effects in cross section comparisons. Studies that analyse carbon intensity at a country level rely on carbon intensity indicators defined as unit of energy or mass of emissions per unit of Gross Domestic Product. In this paper we construct a measure of emissions at corporate level that carefully addresses the emissions profile of energy (and power) companies. Because Oil, Gas, and Energy companies trade energy products at multiple points of their value chains the methodology generally accepted to measure their carbon emissions is stablished by Greenhouse Gas Protocol, which provides the world's most widely used greenhouse gas accounting standards for companies in the Corporate Value Chain Accounting and Reporting Standard. We follow the methodology used by *Science-Based-Targets* initiative (SBTi). [6] Our choice is based on the guidance of the International Energy Agency (IEA) to establish benchmarks and targets and by Transition Pathway Initiative (TPI), a leading independent corporate climate institution that elaborates comparable reporting benchmarks. This requires incorporating scope 1, 2 and 3 in the construction of the emissions intensity variable for the oil and gas sector while only considering electricity generation for the power utility sector.

We analyse the effect of the green factor in the performance of energy corporates in two stages. We first construct two versions of the green-brown portfolios. A first factor will include low carbon utility corporations as green corporations and a second version includes renewable energy producers that are zero emitters as the green portfolio component. We quantify the profitability of long-short positions on low carbon intensity power utilities and high carbon intensity oil and gas corporations respectively. Our empirical results demonstrate that long short positions deliver long term profitability for both Europe and North America. Profitability is enhanced for portfolios constructed with zero emitters. Interestingly, the North American portfolio outperforms the European portfolio. Our results demonstrate that the green factor is significant for the energy as well as for the utilities sector, as a whole. While it exerts a positive effect on the returns of the utility corporations it has a negative impact on energy corporations. This is the case for the North America and Europe based samples used in the analysis. Our results are therefore consistent with the idea that transition risk is important in pricing oil and gas and power utilities portfolios. In a second stage we analyse the alpha generation capability of the green transition factor and demonstrate that the green-brown portfolio constructed with zero emitters is able to generate in the North American case, a positive and significant alpha equal to 9.74% that means an additional excess return in the portfolio.

We can describe "green premium" or "greenium" as a measure of the added value of environmentally friendly activities ("green") in terms of market excess returns as measured by the alpha component. Investors may seek compensation for holding the stocks of high CO2 emitters and therefore for their exposure to associated higher carbon risk, resulting in a positive relation in the cross-section between a firm's CO2 emissions and its stock returns, explaining the existence of the carbon risk premium. The carbon transition risk therefore represents another source of market risk priced in the financial market that in the literature refers to carbon "beta". Bolton and Kacperczyk (2021b)[7] find the existence of a significant "carbon premium" in the US stock market as evidenced by stocks of firms with higher total carbon emissions and changes in emissions earning a higher return. Nevertheless, they find no carbon premium associated with emissions intensity. Their empirical results suggest that investors are pricing in carbon risk and demand compensation for their exposure to idiosyncratic risk factors associated with climate risk. They also find that divestment effects from large investors do not generally explain the

[6] The Science-based targets initiative (SBTi) is developed to stablish targets in different sectors to reduce their greenhouse gas emissions. SBTi is a partnership between Carbon Disclosure Project (CDP), the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF), that establish guidance on setting science-based targets for Oil, Gas and Integrated Energy companies. (Guidance on setting science-based targets.

[7] This adds further evidence against the interpretation that the carbon premium is driven by unexpected return components. Also, suggests that the discount rate channel is an important factor and that carbon risk premia are not just caused by divestment

carbon risk premium that they document. In a similar study Bolton and Kacperczyk (2021a) document the existence of a carbon premium in stock markets, implying that firms with higher emissions compensate investors by offering higher returns. The authors argue that there are no models for the energy transition that can be readily applied to capture carbon-transition risk, but their findings conclude with a significant carbon premium in all sectors, not just in the coal, oil, and gas sector. The carbon premium is positively related to both the level of emissions and the year-to-year percentage change in emissions, controlling for firm specific characteristics that predict returns. The carbon risk is thus captured through a carbon "beta."

A related line of literature has highlighted the inefficiency concerning climate risk pricing. Because the climate risk premium does not appear to be accurately incorporated in market prices. This literature suggests that the risk associated with carbon emissions is underpriced, after controlling for other known risk factors in the literature, such as the market, size, value, and momentum factors (see Venturini 2022 and references therein). Investors in this context can achieve higher returns with appropriate investment strategies. This literature underlines the existence of a carbon alpha delivered by taking long positions in green assets and short positions in brown stocks. Shares of green companies in this context will provide better climate coverage and higher expected returns, and not lower as the factor pricing theory predicts. In the literature referred to as a carbon "alfa." Oestreich and Tsiakas (2015) show how the long dirty short clean strategy decreases in alpha over time.

In this paper we analyze carbon transition risk focusing on the energy and utilities sector. There are several global or multisector studies that address linkage between carbon transition risks and financial returns as in Oestreich and Tsiakas (2015), Jiang and Weng (2019), Alessi et al. (2019), Görgen et al. (2020), Bolton and Kacperczyk (2021a, 2021b), Hsu et al. (2021), Gimeno and González (2021), and Pástor et al. (2021). These studies are not conclusive regarding the sign and significance of the carbon beta and the carbon alpha. Studies focusing on sectorial analysis are more limited. Bernardini et al. (2021), address the effect of carbon risk on stock returns of European electric utilities, while Shaw, F. and Donovan, C. (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 & Weng (2019) analyzes agriculture-related stocks and climate change risks, and portfolios of power renewable stocks and fossil fuel stocks are analyzed by Imperial College Business School and IEA (2021).

To the best of our knowledge there is insufficient evidence of how the financial performance of the energy sector may be affected by the transition to a lower-carbon economy. Particularly we believe that it is important to compare oil and gas companies with other cleaner energy companies and analyze whether there is an impact on their stock price valuations. According to the IPCC Sixth Assessment Report (IPCC, 2021), the largest individual sector contributing to global greenhouse emissions is the energy sector, and therefore the analysis of transition risk through the lens of the energy sector is important to shade light on how this sector can be also part of the solution to a lower-carbon economy. In this paper we aim to compare the energy transition process for the oil has sector in relation to the power sector with the aim to determine whether higher speed of adaptation leads to improved financial performance.

We contribute to current debate by providing additional evidence on the sign of the carbon premium addressing the "alpha" generation as well as the "beta" dimension, for which there is no consensus in the literature. While there are some authors that support the existence of a positive beta carbon premium (see Bolton and Kacperczyk 2021a, Bolton and Kacperczyk 2021b, Hsu and Tsou 2021, Alessi, 2019) a parallel line of literature finds opposite results. Pástor et al. 2021 estimate the equity “greenium” measured as the difference between the implied cost of capital of green and brown stocks is consistently negative when considering expected returns. Other authors show that investors may not require compensation for bearing carbon risk (see Gorgen et al. 2020 and Larcker and Watts 2019 for the bond market). A related line of literature (see Imperial College Business School and EIA report 2021) has compared the performance of low carbon power stocks and fossil fuel stocks finding that there are superior risk returns for renewables when compared to fossil fuels.

This paper is organized as follows. Section 2 provides a description of the methodology which includes a description of the measure of carbon intensity, the description of the construction of the green factor and the econometric framework used to analyse the effect of the green factor on portfolio returns. In section 3 we describe the data and in section 4 we provide empirical returns. We conclude in section 5.

2. Methodology

2.1 Measuring carbon intensity in the oil and gas and utilities sectors

In order to construct a green transition factor we need to apply a measure of emissions intensity suitable for the oil and gas as well as for the power generation sector. One of the major challenges of this analysis is to construct a data set that makes the energy (oil and gas) sector comparable to the cleaner energy power-utilities sector. In what follows we discuss how the data set is constructed to fulfil this purpose. We consider the efficiency of the energy production process to allow measurement of a carbon emissions indicator based on corporate activity.

In order to quantify the importance of emissions in the oil and gas companies, we follow the evolving boundaries description of the Science-based targets initiative (SBTi) which establishes objectives in different sectors to reduce their greenhouse gas emissions considering the three categories of emissions.[8]

The proposed SBTi carbon intensity measures are to be compared with Cleaner Energy producers which embed the power electricity sector. Our starting point in this context is to measure carbon emissions performance in the power utilities sector only coming from electricity generation. This is consistent with the methodology established by the IEA and the TPI.

2.2 Construction of the Green Transition factor

Our aim is to construct a proxy for energy transition risk for the oil and gas sector. This consists of a portfolio that longs low polluting power utilities and shorts highly polluting corporates that operate in the oil and gas sector. In order to construct the carbon transition factor based on long-short portfolios, we have selected a carbon emissions intensity measure. Oil and gas and

[8] See appendix 1 for details on the different scopes of emissions and the Science based target initiative (SBTi)

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 select their activity component in the same way that companies report their public target commitments to reduce their emissions in order to capture the energy efficiency component. For the oil and gas companies the emissions are measured in relation to energy produced in mega joules, while electricity companies are in megawatts per hour. To homogenize units we translate electricity sector emissions initially measured in "metric tons of CO2 equivalent per megawatt hour" to "grams of CO2 equivalent per mega joule" using the conversion factor of $1x10^6$ divided by 3600.

Our sample starts in January 2014 due to the availability of carbon emissions data and ends in December 2020. Corporates emissions data used in the construction of the green transition factor focuses on oil and gas companies and power utility producers covered by the TPI initiative. As a second filter, we require that companies are domiciled in two geographies Europe and North America which have particularly intensified scrutiny of emissions in the energy industry in recent years.[9] The sample comprises privately owned companies based in Europe and North America, including European state-owned companies. A second version of the green transition factor also identifies pure renewable energy companies applying the Bloomberg Industry Classification Systems (BICS). We restrict our selection to renewable generation companies, consistent with the criteria previously established with power electricity companies and thereafter group them by European and North American portfolios. The portfolio of renewable energy generation companies requires a market capitalization above USD 200 million to ensure stock liquidity.[10]

2.3. Inclusion of the green factor in the Cahart four factor model

Following similar approaches in the literature (see Gimeno and Gonzalez 2002) this paper extends the Carhart (1997) four factor model to allow for the following specification:

$$r_{p,t} - r_f = \alpha + \beta_1(R_{M,t} - r_f) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \beta_5 GF_t + v_t \quad (1)$$

where $r_{p,t} - r_f$ is the excess return of portfolio *i* over the risk-free interest rate in day t, GF_t is the time series value of the green factor. Portfolio returns 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 aim is to analyze whether the green factor has explanatory power at time series portfolio level and to analyze the sign and significance of the β_5 parameter to address the existence of a transition risk premium.

In a second stage, we analyze the extent to which the green factor exhibits alpha by estimating the following specification:

$$GF_t = \alpha + \beta_1(R_{M,t} - r_f) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \epsilon_t \quad (2)$$

[9] See Page 34 “The Oil and Gas Industry in Energy Transitions” IEA 2020).

[10] Our methodology is aligned with the IEA and the Centre for Climate Finance & Investment (2021) analysis of Clean Energy companies .Full article available at: Clean Energy Investing Global Comparison of Investment Returns - Imperial CCFI and IEA 427.pdf

Note that this later approach has been widely used in the green factor literature, important examples include Oestreich, Tsiakas (2015), Bernardini, et al. (2021), Hsu et al. (2022), Gimeno and González (2022) and see Halbritter et al. (2015) in the ESG literature.

3. Data

We have selected FactSet to provide daily data of stock prices of the selected corporates. 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 data for the European and North American oil and gas corporates for which we have carbon intensity available data according to the TPI criteria for the 2014-2020 sample period. This delivers a sample with a maximum of 10 corporates for Europe (European energy) which are matched with European power utility firms (European utility) ranked on the bases of their carbon footprints. The same logic is applied for North American firms. The total number of North American oil and gas firms is 25 (North American energy). If the carbon intensity data is missing for a given year for a certain corporate the firm is excluded from the portfolio. We match the selected number of oil and gas and North American firms (North America energy) with the corresponding power utilities (North America utility) ranked on the basis of carbon intensity. While the number of firms considered changes due to missing data and to create the equally weighted portfolios, we can summarize the starting sample as follows.

Summary of number of firms considered in long short portfolios For the 2014-2020 period	
Geographical area and sector	Initial Number of firms
European energy	10
European utility	21
European zero emitters	33
North American energy	25
North American utility	39
North American zero emitters	16

A second approach to constructing the green transition factor involves long positions in zero emitters power corporations. The BIC classification criteria delivers 16 corporations of these characteristics in US and Canada. After we dropping firms with missing data, we finally have 12 zero emitting firms. We thus select the 12 most polluted firms from the sample of 25 North American energy on a yearly basis based on the proposed carbon intensity measure. When we construct the zero-emitter portfolio for EU or method is slightly different. Given that there are 10 EU energy firms in our sample, we choose the top 10 zero emitters (from an initial sample of 33 sample firms) according to their market capitalization.

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 annually the portfolios and for each year the selected firms are different. This is a criteria not always followed by literature.

Extended Carhart (1997) regressions require that daily closing prices for a representative sample of energy and utilities corporations in North America and in Europe. The constituents of four indexes are analysed for this purpose (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 utilities sectors in North America respectively. b) Europe/Energy Minerals (FS2100R3, 60) and Europe/Utilities (FS4700R3, 96) which were applied to analyze the corresponding European oil and gas and utilities sector. All prices of index components are in dollars and all indexes considered are exchange traded.

As a result, the number of companies considered in the entire energy sector sample is 83, in North America 23 and 60 in Europe, while the entire utility sector sample is 151, in North America 55 and 96 in Europe. The data source for the whole sample is FactSet.

The data library for the Fama-French 3 factors and the Carhart factor, as well as the risk-free rate, are available on Kenneth French's website; nevertheless, the industry portfolios are only available for USA stocks and on monthly basis. For this reason, we select the time series of North American and European factors for the whole market from these regions, which are available daily data in the developed markets factors and returns section. Also, the time series for these observable factors, based on the whole market, will reduce the correlation with our industry-based green transition factor.

4. Empirical Results

4.1. The performance of Long short portfolios and construction of the green factor

Constructing long short portfolios with high and low polluters is one of the most common methods applied to investigate the relationship between the green factor and corporate performance. Here we build two types of long short portfolios. With the available TPI carbon intensity data we sort on a yearly basis for each geographical area companies by their carbon intensity metric and select the oil and gas corporates with the most polluting record for the short position. We simultaneously long the power corporations with the lowest carbon intensity reported metrics. Once firms have been classified as low emitters and high polluters we form equally weighted portfolios and calculate daily returns.

As means of robustness and in order to identify the effects of different speeds of transition on portfolio returns, we create an alternative green factor constructed with long positions in zero emitters and short positions in high polluters oil and gas producers for each of the geographical areas considered. We expect that using long positions on zero emitters will outperform its low carbon emission counterparts as investors will prefer investment in advanced zero emission technologies that have reached the final target in the energy transition. Because we cannot rank zero emitters in terms of carbon emissions, the construction of zero emitters requires that we match the total number of oil and gas corporations with zero emitters in each geographical area.

If there are less oil and gas companies than zero emitters for a given year then match the oil and gas with the same number of zero emitters.

In what follows we report profitability from long short portfolios cumulative returns are then calculated for long only and long-short positions. As a preliminary analysis figs 1a-2a in the appendix 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. (low emitter NA, polluter NA, low emitter EU and polluting EU). In fig 3a we illustrate cumulative returns for zero emitters in NA and EU respectively. We can see a common feature across all portfolios. The profitability decreases during the 2014-2015 price collapse and during the 2020 COVID crisis for both portfolio types. This is consistent with the reported patterns in the literature (see Gimeno and Gonzalez 2022). The general result for the NA case is that long only investments in zero emitter energy producers deliver higher cumulative returns that long only investments in polluting energy corporations. For EU based corporations the outperformance of clean power companies becomes evident only after 2020. As it is the case in 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 in figs 1a and 2a. Cumulative returns for the zero emitters are however positive during most of the sample period. Important exceptions include short episodes 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 presidency announcing in June 2017 the withdrawal of 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.

The performance of portfolios that long low carbon power companies and short polluting energy corporations are provided in table 1 and Fig 1 of the main text. We define their cumulative returns as a green transition factor. A close look to fig 1 which exhibits the time series evolution of cumulative returns of the green transition factor shows that while outperformance is clear from 2015 for the North American case, positive profitability of the green factor in the EU is only documented from 2020. This suggests that the collapse of stock prices in energy corporations during the COVID crisis and pronounced recovery in its aftermath (in relation to the low carbon power utilities 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 crisis and 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 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).

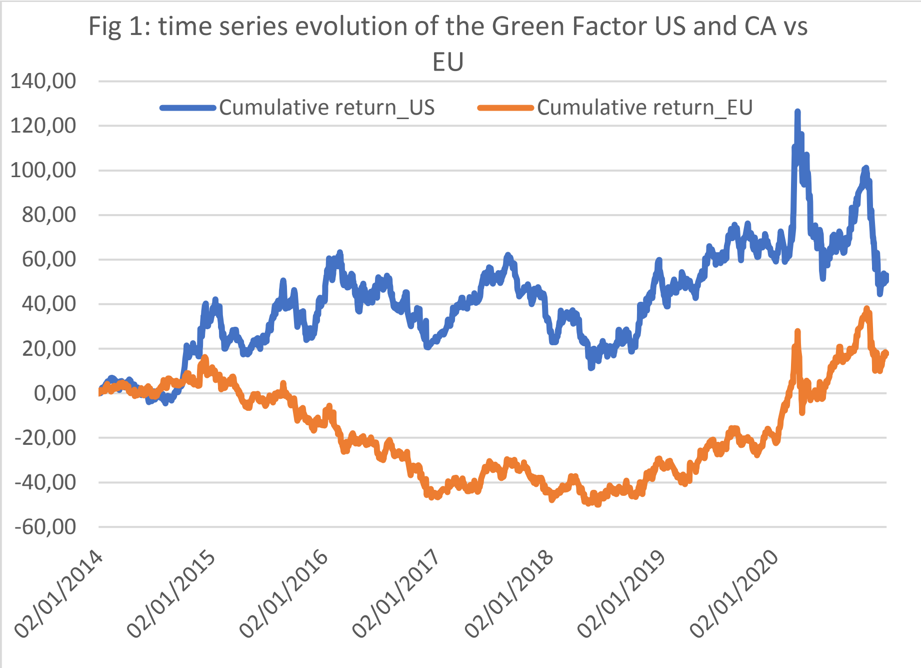

Fig. 1: Time series evolution of the green factor built as a portfolio long with low carbon power utilities and short with short polluting energy corporations in North America and Europe.

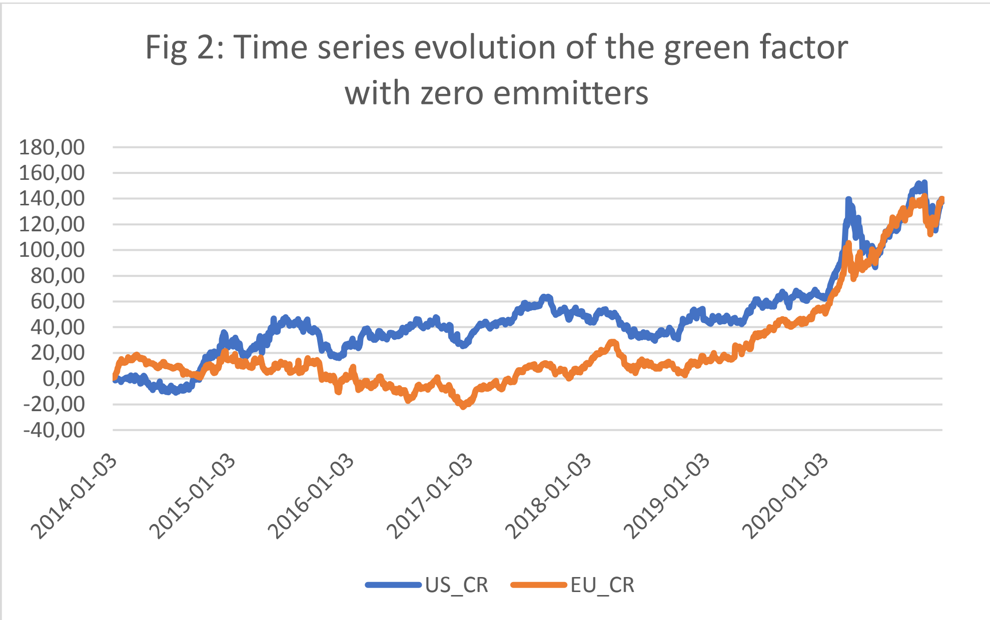

Fig. 2: Time series evolution of the green factor built as a portfolio long with the zero emitters renewable energy producers and short with polluting energy corporations in North America and Europe.

The time series evolution of the green transition factor for the zero emitters case is illustrated in fig 2. A close inspection of this figure suggests that cumulative returns are on average higher and less volatile than under the low carbon utilities counterpart illustrated in fig 1. under this portfolio as well as a closer performance of the NA and EU case. Cumulative returns are negative in the case of the EU portfolio for a shorter period (namely Nov 2015-May 2017) than in fig 1. The performance of the low carbon emissions and zero emissions based transition factors are quantified in the upper and lower panels of table 1 respectively.

This reports 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 is positive for both NA and EU, risk adjusted returns as measured by the Sharpe ratios remain highest for the US long short portfolio. Reported evidence is consistent with the idea that increasing climate change awareness in the last years have has shifted investor demand towards green asset. This is true since 2015 for the NA case and in the post COVID era in the case of Europe. Results reported in the lower panel show that the green factor based on zero emitters delivers is outperformance with respect to the low carbon utilities counterpart for both NA and EU. The improved performance arises from significantly higher average returns in relation to volatility. Average returns increase from 7.81 and 2.65 in NA and EU respectively to 20.44 and 20.66 respectively in the zero emitters portfolio. There is therefore notable difference for the EU case. The reported positive performance of both measures of green transition factors are consistent with the green factor literature (see Gimeno and González 2022 and Ilhan et al 2021) and also suggest that investors require compensation for transition risk.

Table 1: Descriptive statistics of cumulative returns of the green factor portfolio: NA vs EU, 2014-2020

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: t-statistics based on Newey-West (1987) standard errors in parentheses.
The asterisks *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels respectively.

One open question relates to the time lapse between carbon emissions are available and the calculation for the portfolio returns. In our analysis we use carbon emissions intensity data in year t to explain daily returns over the same year t. This could introduce a look-ahead bias and we might inadvertently relate stock returns during year t to emission data that might not yet have been available to investors. To address this question, we followed a robustness check considering daily stock returns with a one-year lag to reflect the time lapse when emissions are reported, and stock returns are realized. Reported results (see table 1a and fig 4a– in the appendix) show that results are robust to the use of the lagged value of the carbon intensity measure.[11]

4.2. **Measuring the effect of the green transition at portfolio level**

We now proceed to analyse the effect of the green factor as an explanatory variable of corporate performance for both energy and utility corporations in EU and NA. We construct for this purpose two portfolios for each geographical area, one with all the oil and gas corporations traded in the NA and EU areas, and a second one with the sample of all the utility sector considered in the analysis under both areas. Energy and power portfolios are then regressed against the simple Carhart (1997) four factor model as well the extended Carhart framework with the green transition factor as specified in equation (1).

The coefficients are estimated estimating a linear regression while v_t represents the residual. Robust standard errors are estimated under the Newey and West (1987) procedure

Panel Results for the oil and gas portfolios case are reported in table 1. Results in panel A demonstrate that the inclusion of the green factor has a significant impact on portfolio returns of NA energy corporates. 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 two are compared. Indeed, while the estimated alpha is negatively and statistically significant under column 1 it becomes negative but not statistically significant under column two of table 1. The measurement of transition risk through the proposed risk factor also leads to an increase in the reported adj.R^2, which moves from 0.71 in column 1 to 0.85 in column 2. Accounting for the new factor 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.

The last two columns of table 1 report estimated coefficients for the benchmark and extended model under the EU energy portfolio. Regression results demonstrate that the green transition factor has a negative and significant effect on the European energy portfolio returns. The impact on portfolio returns is however lower than that reported for the NA case. This can be seen in the estimated size of the coefficient corresponding to the green transition factor, the

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

adj. R^2, and the estimated alpha. The estimated coefficient of the green factor in column 4 is -0.34, 0.20 points lower in absolute value than that reported for the NA case. The reported adj.R^2 under column 4 is 0.7. While this is seven 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 larger for the NA estimates. Lastly, we see no significant difference between the alpha coefficients reported in tables 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, decreases moderately the effect of the value and the market factors but increases the impact of the size factor. On the other hand, 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 relationship between the green factor and the value and momentum factors have been addressed by Pastor et al (2022) who show that 80% of the HML´s alpha and all the momentum alpha disappear after controlling for the strong performance of the green factor. These results are consistent with those reported in table 1 which show a clear outperformance of the green factor in NA when compared to the EU case. The overall conclusion that can be obtained from Table 2 is that the energy transition requires a greater reliance on low carbon producer technologies which has the impact of lowering expected returns on energy corporates. This implies that the green transition factor can explain the evolution of stock prices of energy corporations.

Table 2: 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

Note: t-statistics based on Newey-West (1987) standard errors in parentheses.
The asterisks *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels respectively.

Table 2a: 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: t-statistics based on Newey-West (1987) standard errors in parentheses.
The asterisks *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels respectively.

Notes to table 2 and table 2a: Panel results for the energy sector portfolios regressed against the simple Carhart (1997) four factor model extended with the green transition factor, GREEN (In table 2 built as a portfolio long with the low carbon power utilities and short with high polluting oil and gas corporations and in table 2a 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); the Fama & French (1993) SMB (small minus big) and HML (high minus low) and the Carhart (1997) MOM (winners minus losers). Left columns are the regressions for the North American portfolio and right columns for the European.

Results from analysing the impact of the green factor in the power portfolio are reported in table 3. Reported results in columns 2 and 4 demonstrate that the green transition factor has a positive effect on returns in utility corporates in both geographical areas considered rewarding power 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 2 and 3 show that the absolute values of the green transition factor are notably higher for energy portfolios than for utility portfolios. The return penalization for the oil and gas sector is greater than the reward obtained by corporates in the power sector. Reported market betas are much lower than those shown in table 2 reflecting the fact that utility corporations are defensive stocks. The impact of the size factor is much lower than that reported in table 2. In fact, the size factor is not significant for the NA case as shown in column 2 of table 3. 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 et al. 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 observed 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 table 3. 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 long short portfolio with low-carbon utilities, as reported in table 1.

Table 3: 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: t-statistics based on Newey-West (1987) standard errors in parentheses.
The asterisks *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels respectively

Note to table 3: 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); the Fama & French (1993) SMB (small minus big) and HML (high minus low) and the Carhart (1997) MOM (winners minus losers). Left columns are the regressions for the North American portfolio and right columns for the European.

Table 4 reports results for utility corporations when the green transition factor is constructed with renewable energy companies that are zero emitters. A comparison between table 3 and table 4 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 is 0.06 and therefore significantly lower than that reported for the NA case table 3, 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 3.

Table 4: 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: t-statistics based on Newey-West (1987) standard errors in parentheses.
The asterisks *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels respectively.

Note to table 4: 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); the Fama & French (1993) SMB (small minus big) and HML (high minus low) and the Carhart (1997) MOM (winners minus losers). Left columns are the regressions for the North American portfolio and right columns for the European.

The green factor is however generally not highly correlated with the other benchmark factors. Indeed, correlation results between the Fama-French factors are recognized by the authors, (Fama & French 2015), and our results in tables 5 and 6 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 before, and the negative correlation with the value factor is also consistent with Pastor et al. (2022) which reflects the fact that value stocks are more often brown than green.

4.4. Analysis of the alpha of the green transition factor

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 factor is significant in explaining returns. The next step is to quantify the extent to which the portfolio generates alpha. Reported results in table 7 demonstrate that only the NA 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 green factor portfolio with zero emitters was outlined in Table 1. While the green factor portfolio with zero emitters do not outperform in the estimated slope coefficient it does outperform its low carbon counterpart in terms of the alpha.

Based on our proxy to measure 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.

Table 7: Long short portfolios with polluting oil and gas corporations and low (or zero) emissions portfolios

	Green factor based on lower carbon intensity				Green factor based on zero carbon intensity			
	NA green		EU green		NA zero emitters		EU zero emitters	
		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 to table 7: 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

5. Conclusion

Energy corporates are heavily exposed to carbon-transition risk as the global economy fights to transform the economy from fossil fuels to green energy. We construct a green factor capturing the carbon transition risk premium for the oil and gas as well as utilities sectors based on long-short positions with high versus low polluting corporations within the oil and gas and utilities sectors respectively. Highly polluting companies are identified from the oil and gas sectors, and low polluting companies are selected from power utilities based on low carbon technologies and zero-carbon emitters from renewable energy producers. Electricity generators with energy mix more oriented towards fossil fuels are therefore not considered for green factor construction. A carbon intensity measure from TPI data for North America and Europe is used for this purpose. Using a sample of daily data from the benchmark energy and utilities indexes in North America and Europe we find that green factor delivers positive risk adjusted returns in both geographical areas considered. We also explore the effect of the green factor in explaining returns. While it has a negative and significant effect in explaining returns of oil and gas corporations it exerts a positive and significant effect in explaining returns in the utility sector. An alternative green factor constructed with zero-carbon emitters from renewable energy producers contributes to the explanation of returns and delivers a positive alpha. 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.

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.

Reported results collaborate the view that investments in low emitting technologies provide a hedge of climate change risk. Results are relevant for investors and equity analysts that need to incorporate the effects of transition risks in their portfolios and for energy companies that aim to measure their corporate performance in the energy transition. Our results do therefore contribute to the portfolio allocation process by suggesting that the green factor should be considered to mitigate risk during the energy transition while exploiting return opportunities**.**

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Appendix A:

Detailed Description of construction of Green transition Factor

In order to construct a green transition factor we need to apply a measure of emissions intensity suitable for the oil and gas as well as for the power generation sector. One of the major challenges of this analysis is to construct a data set that makes the energy (oil and gas) sector comparable to the cleaner energy power-utilities sector. In what follows we discuss how the data set is constructed to fulfil this purpose. We consider the efficiency of the energy production process to allow measurement of a carbon emissions indicator based on corporate activity.

In order to quantify the importance of emissions in the oil & gas companies, we follow the evolving boundaries description of the Science-based targets initiative (SBTi) which establishes objectives in different sectors to reduce their greenhouse gas emissions considering the three categories of emissions.[12] SBTi is a partnership between Carbon Disclosure Project (CDP), the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF), that establishes guidance on setting science-based targets for Oil, Gas and Integrated Energy companies.[13] The sector is composed of oil and gas (O&G) companies, as well as Energy companies with oil and gas activities – that are no longer strictly just producing Oil and Gas, which means that they can be considered as companies that are already in transition.

The measurement of carbon emissions in the oil and gas sector is a challenge. Oil, as, 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 stablished by the Greenhouse Gas Protocol, which provides the world's most widely used greenhouse gas accounting standards for companies in the Corporate Value Chain (Scope 1, 2 and 3) Accounting and Reporting Standard. [14]

The proposed SBTi carbon intensity measures are to be compared with Cleaner Energy producers which embed the power electricity sector. Our starting point in this context is to measure carbon emissions performance in the electricity utilities sector only coming from electricity generation. This is consistent with the methodology established by the IEA and the TPI. We argue that that while the largest electricity companies are involved in distributing or retailing electricity generated by other companies or are significantly engaged in other activities such as gas distribution and retail, our carbon intensity measure covers all power-sector emissions and is therefore consistent with the IEA targeted benchmarks.

Concerning the corporate boundary with affiliates, the equity-share approach, or the control approach, we follow the criteria adopted by the TPI, which implies accepting the measure chosen by companies in their emissions reporting, as long as they are representative and consistent to report emissions and activity in the same boundary.

Our sample of corporates used in the construction of the green transition factor focuses on oil and gas companies and power utility producers covered by TPI. As second filter we require that companies are domiciled in two geographies Europe and North America. The sample comprises privately owned companies based in Europe and North America, including European state-owned companies. These geographies have particularly intensified scrutiny of emissions in the

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[12] See appendix 1 for details on the different scopes of emissions

[13] Details available at https://sciencebasedtargets.org/resources/legacy/2020/08/OG-Guidance.pdf

[14] See https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard-EReader_041613_0.pdf

energy industry in recent years, as 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.[15]

Companies in the oil and gas sector are classified according to IPIECA and the IEA, which group oil and gas companies into the following three main categories:[16] a) National oil companies (NOCs) that concentrate on domestic production international NOCs (INOCs) that have both domestic and significant international operations; the classification is done based on upstream operations. b) Privately owned (publicly traded) companies: The "Majors", sometimes referred to as international oil companies, (IOCs) or integrated energy companies (IECs) and "Independents" that are either fully integrated companies, like the Majors but smaller in size, or independent upstream operators. The "Majors" are integrated companies listed on US and European stock markets. c) Privately owned remaining company types, mainly: Service companies (specialist engineering services for drilling, reservoir management and construction of infrastructure), pure downstream companies (operating refineries, and retail networks), trading companies which are usually active in the physical trading of oil products and LNG transport, refining, distribution, and storage.
The third filter imposed for company selection is that companies are traded in liquid exchanges and they provide a reliable disclosure of information about carbon emissions and energy produced. Our sample of oil and gas companies comprises publicly owned companies (Majors IOCs or integrated, independents and pure downstream companies) with the exception of (Equinor, formerly Statoil in Norway)

The sample with cleaner energy producers also comprises privately owned companies based in Europe and North America, including European state-owned companies, if any. This way, cleaner energy producers will be classified from the universe of the energy companies that have the lowest carbon emissions indicator, starting with power utilities and finishing with renewable energy companies, that have zero emissions intensity.

Our analysis uses different data sources. The primary source of carbon emissions data is the Transition Pathway Initiative (TPI) to recollect the data for the oil and gas companies, as well as the power utilities. To classify the renewable energy producers the selected data base is Bloomberg.

There is a limited number of databases that recollect corporate disclosure about sustainability metrics, such as carbon emissions. Here we need a recognized methodology applied in the oil and gas sector to make companies comparable on homogeneous basis and with the power utilities. Measuring carbon risk in the financial market requires the expertise and knowledge of specialized institutions dedicated to developing frameworks and benchmarks to compile carbon and transition-related information. We have chosen for this purpose the Transition Pathway Initiative which provides also open access database, sourced on publicly disclosed company information provided by FTSE Russell.

[15] See Page 34 "The Oil and Gas Industry in Energy Transitions" IEA 2020).
[16] Full description available at https://www.iea.org/reports/the-oil-and-gas-industry-in-energy-transitions

Appendix AA:

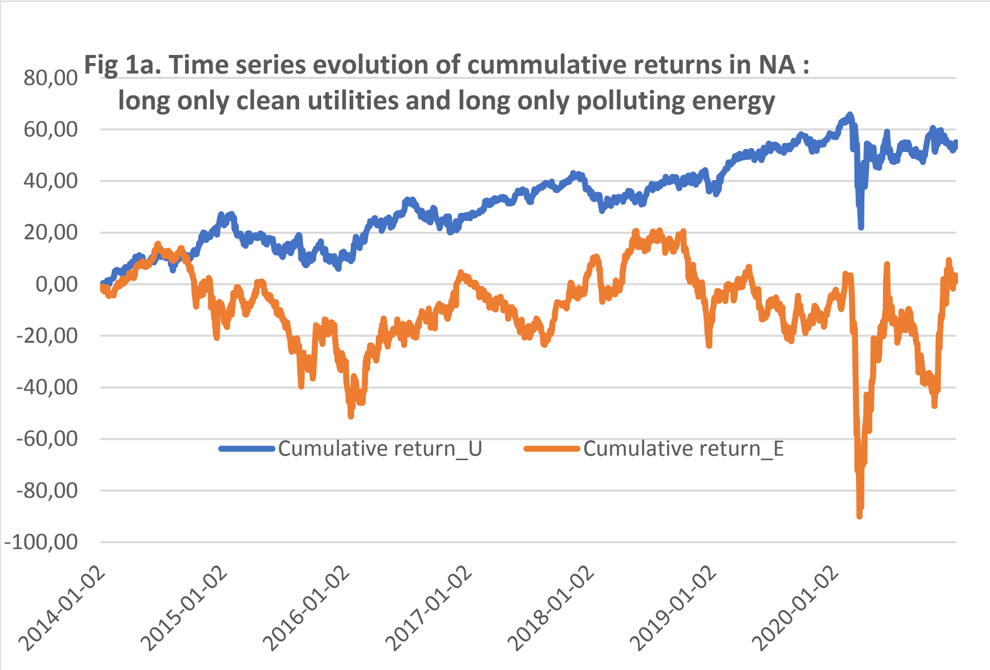
Tables:

Table 1AA: Summary statistics for green factor performance with use of lagged carbon intensity measure

Summary (%)	Mean	Stdev	Sharpe	Max	Min	Skew	Kurtosis
North America	5.860	34.689	0.169	18.499	-15.156	-0.222	9.969
EU	4.148	21.815	0.190	10.316	-9.823	-0.627	8.577

Appendix B

Graphical Appendix



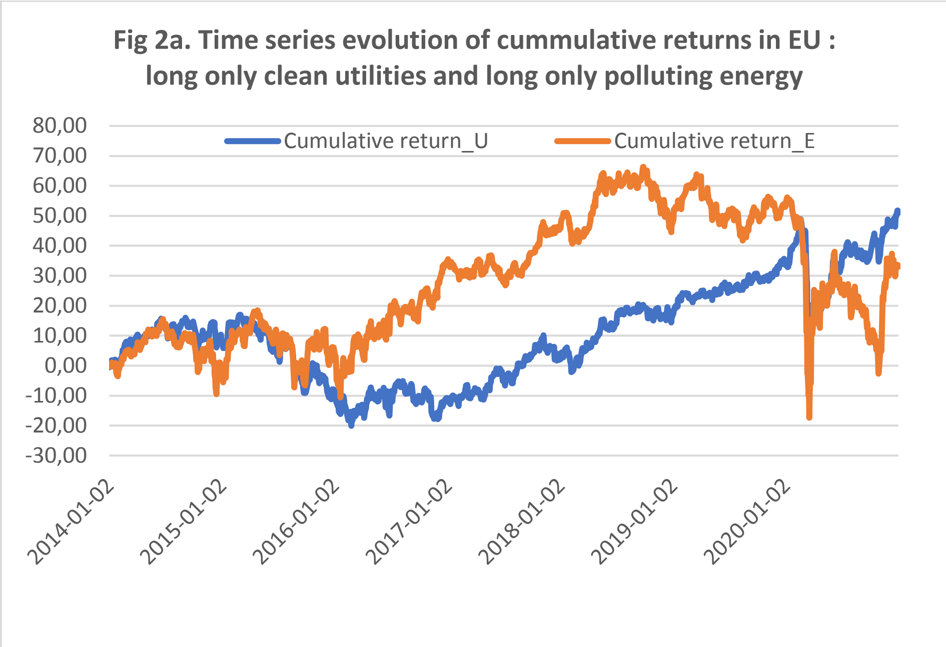


Fig 2a. Time series evolution of cummulative returns in EU : long only clean utilities and long only polluting energy
Cumulative return_U
Cumulative return_E
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
-10,00
-20,00
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2020-01-02

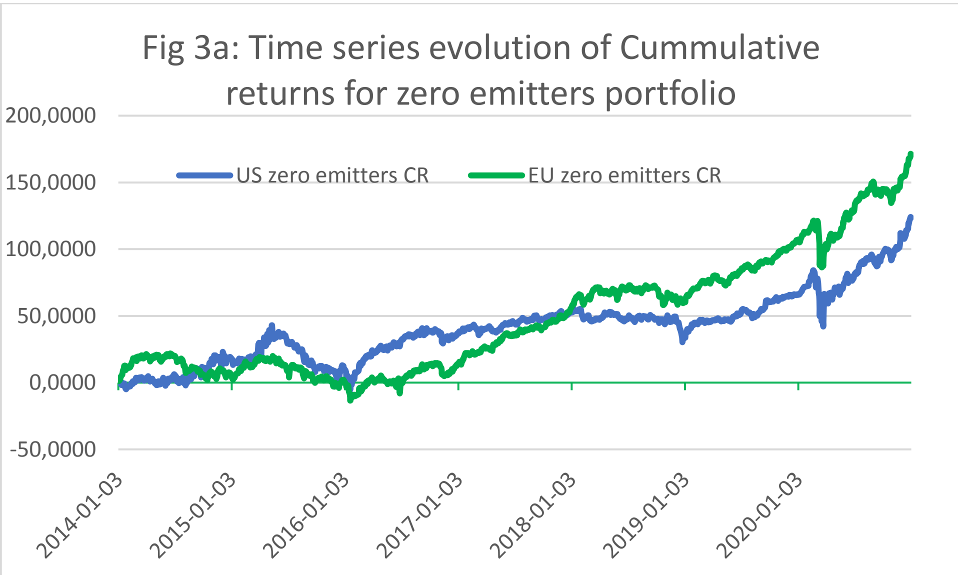
Fig 3a: Time series evolution of Cummulative returns for zero emitters portfolio
US zero emitters CR
EU zero emitters CR
200,0000
150,0000
100,0000
50,0000
0,0000
-50,0000
2014-01-03
2015-01-03
2016-01-03
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2019-01-03
2020-01-03

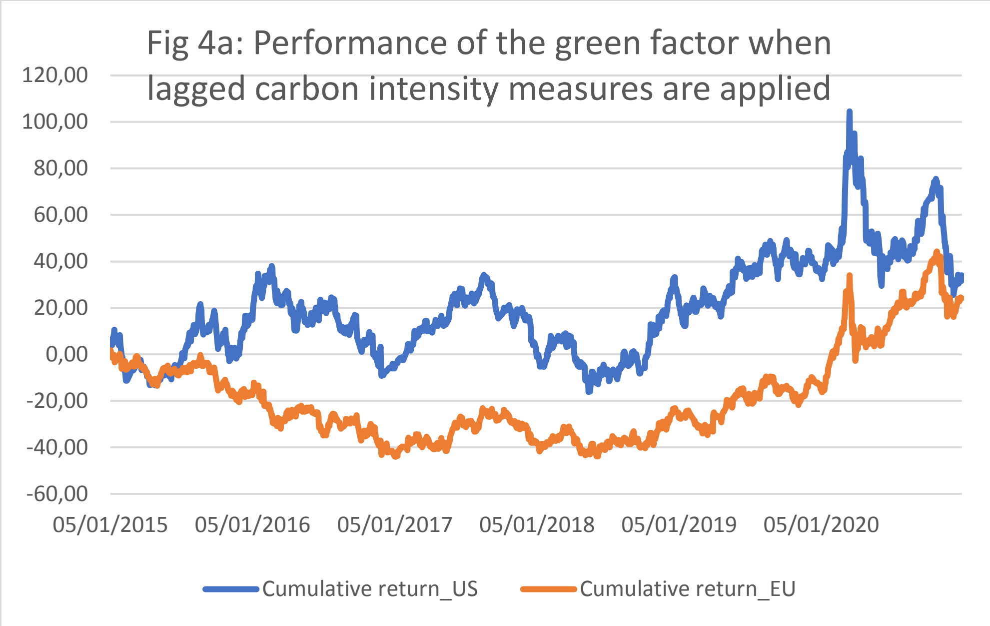

Table 5. Correlation matrix between the green factor based on the power utilities portfolio and the rest of the factors

North America

	Green factor	Mkt-RF	SMB	HML	MOM
Green factor	1,00				
Mkt-RF	-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-RF	SMB	HML	MOM
Green factor	1,00				
Mkt-RF	-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

Table 6. 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-RF	SMB	HML	MOM
Green factor	1,00				
Mkt-RF	-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-RF	SMB	HML	MOM
Green factor	1,00				
Mkt-RF	-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