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ORIGINAL ARTICLE

Portfolio benefits of taxonomy orientated and renewable European electric utilities

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Abstract

This paper investigates carbon and energy mix risk in the equity prices of EU-Taxonomy orientated and renewable European electric utility companies. We calculate carbon intensity and energy mix factors to measure possible carbon and energy mix premia while investigating the performance of portfolios of EU-Taxonomy orientated and renewable European electric utilities. We use a unique dataset to extend the three-factor model presented by Fama and French (1993) and find evidence of a positive renewable energy mix premium for portfolios of EU-Taxonomy orientated firms and firms with a high level of renewable energy in the energy mix. A positive low-carbon premium is also found for these same portfolios. Lastly, based on the three-factor model, an EU-Taxonomy orientated portfolio outperforms both a non-orientated portfolio and a non-reporting portfolio while a renewable energy portfolio outperforms a conventional energy portfolio. Our results are important for regulators, investors and European electric utilities in assessing the impact environmental regulations have on a firm's cost of capital.

Keywords Taxonomy · Factor model · Asset pricing · Renewable energy · Carbon risk · Carbon intensity

JEL Classification G1 · G110 · G120 · Q520

Introduction

"*If you do not change direction, you may end up where you are heading*."[1] Over the course of the last 17 years, the role finance plays in changing the direction of global warming has been solidified by the European Commission (EC). The EC demonstrated a willingness to transition to a climate compatible economy with the introduction of the *European Emissions Trading System* (ETS) in 2005.[2] This goal was confirmed by the European Union (EU) on the world stage with the signing of the *Paris Agreement* aiming to limit global warming to well below 2°C compared to pre-industrial levels.[3] The EC recently released a roadmap to achieve this goal: the *Strategy for Financing the Transition to a Sustainable Economy*.[4] This transition's success is partly dependent on the EU-Taxonomy[5] (hereafter referred to as the taxonomy), which creates a uniform definition of certain sustainable activities. This taxonomy should allow investors to better assess a company's capital expenditures in, e.g., renewable energy projects. Changing how electricity is produced in Europe represents an integral part in achieving the European climate goals since the supply of energy accounts for more of Europe's greenhouse gas (GHG) emissions than

[1] Attributed to Lao Tzu.

[2] Directive 2003/87/EC (2003).

[3] Paris Agreement (2015).

[4] European Commission (2021b).

[5] European Commission (2021a).

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any other single activity.[6] Consequently, European regulators are setting signals to reduce the carbon intensity of energy production and green the fuel mix of this production (e.g., the taxonomy sets limits for which activities can be considered sustainable based on both the carbon intensity of electricity production and the source of energy used in the production). The EC's *climate and energy package*[7] set goals to reduce GHG emissions by 20 percent[8] while increasing the share of renewables in the energy mix to 20 percent by 2020. Furthermore, the EC set a 40 percent GHG emission reduction goal in 2014[9] to be achieved by 2030 which was then later raised in September 2020 to a 55 percent reduction with at least 65 percent of Europe's energy coming from renewable sources.[10] Finally, the GHG emission reduction goal was expanded to at least 80 percent by 2050 in the *energy roadmap.*[11] The recent regulatory developments lead us to pose the question whether investors could have perceived an increased (decreased) risk in holding high-carbon (low-carbon) emitting or conventional (renewable) electric utilities. We identify two important reasons for examining whether investors have adjusted their risk perceptions concerning electric utilities. First, companies could benefit from better understanding how investors view risks associated with the transition to a carbon neutral economy. For example, if investors have adjusted their risk perceptions due to regulatory pressure, companies' cost of capital should have been adjusted. Second, the paper's findings could be used by regulators in developing future regulations targeting climate change and the transition to a carbon neutral economy. Despite the urgent need for research on renewable infrastructure due to the important role it plays in achieving carbon neutrality, Gupta and Sharma (2022) demonstrate in a systematic literature review on infrastructure that such research is scant. This paper contributes to the literature on a subgroup of infrastructure, electric utilities, by examining the financial performance of green and brown electric utilities in a time of regulatory evolution. We provide evidence on the performance of green and brown electric utilities which could help companies and regulators master the transition to a carbon neutral economy.

In order to investigate our research question, we build on the efficient market and market equilibrium theories. According to the *efficient market hypothesis* from Fama (1970), markets should quickly incorporate any relevant information into a security's price. Therefore, if investors deem the recent regulations to raise (lower) the risk premium for high-carbon and conventional (low-carbon and renewable) electric utilities, we would expect this information to lead to higher (lower) costs of capital for such firms. Investors' non-pecuniary tastes à la Fama and French (2007) could also explain why investors might be willing to pay more for sustainable companies thereby lowering their expected return while raising the realized return (Pástor et al., (2021); Stotz (2021) Moreover, Pástor et al. (2021) argue that brown i.e. environmental sinners, stocks could be devalued compared to green, i.e. environmentally friendly, stocks if the government fines brown stocks due to an unforeseen worsening of the climate. Based on the previous literature, we expect markets to adjust their risk perception for low-carbon and renewable utilities which should lead to a short-term outperformance over high-carbon and conventional utilities. Additionally, we expect to see a gradual decrease in the cost of capital for low-carbon and renewable European companies over the last decade as the goals set by regulators were strengthened. This expectation means that renewable energy and low-carbon utilities can be expected to have outperformed conventional energy and high-carbon utilities in the last decade. We argue that the case can be made that this outperformance is due to investors lowering the expected return from renewable and low-carbon utilities causing higher realized returns in our timeseries. Our findings suggest that the European electric utilities market is not yet in a state of green/brown equilibrium à la Pástor et al. (2021).

This research uses a unique hand-collected dataset to examine the performance of portfolios comprising listed European electric utilities (EEU) to determine if there is evidence of either carbon risk or energy mix risk[12] premia for this group. We create portfolios based on taxonomy orientation and levels of renewables in the energy mix. We show that portfolios of taxonomy orientated and renewable EEU outperform portfolios of non-taxonomy orientated and conventional EEU. Furthermore, we find evidence of carbon risk and energy mix premia for EEU in the period we examine. These findings are robust to various adjustments in the calculation of the risk factors employed in our model. To the best of our knowledge, we are the first to examine the performance of portfolios comprising EEU based on taxonomy orientation while including the possibility of carbon and energy risk premia for such portfolios.

The rest of this paper is structured as follows. First, a brief introduction to factor and carbon risk literature is given and our hypotheses are presented. Second, the data and model

[6] European Commission (2020a).

[7] Directive 2009/28/EC (2009); Directive 2009/29/EC (2009).

[8] The goals from the EC are all compared to levels in 1990.

[9] European Commission (2014).

[10] European Commission (2020b).

[11] European Commission (2011).

[12] The risk associated with having a large share of non-renewable fuels used in producing electricity, since non-renewable fuel sources should be phased out in order to achieve climate neutrality.

used in analyzing the data are explained. Third, the results of this analysis are presented and discussed. Lastly, concluding remarks are made.

Literature and hypotheses

Since Fama and French (1993) extended the *Capital Asset Pricing Model*[13] with two further factors representing size and value, researchers have expanded the list of factors attempting to explain abnormal returns, e.g., Carhart (1997) added a momentum factor, Amihud (2002) found evidence of an illiquidity premium and (Novy-Marx 2013) observed a gross profitability premium. Hübel and Scholz (2020) extended the 5-factor model from Fama and French (2015) with Carhart's momentum factor and 3 factors based on environmental, social and governance scores. They find the 3 ESG-factors significantly add to the explanatory power of the extended Fama and French model. Stotz (2021) investigated the realized and expected returns of a portfolio long high-ESG companies and short low-ESG companies. He found a higher (lower) realized (expected) return in his US sample from 2008 to 2018. Other literature has focused on the existence of additional green or carbon premia. Koch and Bassen (2013) uncovered a carbon premium leading to increased capital costs for EEU with a very carbon intensive energy mix from 2005 to 2010. Oestreich and Tsiakas (2015) investigated German companies affected by the EU emissions trading system and uncovered a carbon premium for firms with high emissions. Monasterolo and Angelis (2020) investigate the systematic risk associated with carbon intensive and low-carbon indices and find that investors started overweighting low-carbon investments after the Paris Agreement. Choi et al. (2020) find that carbon intensive companies underperform in areas with higher than normal temperatures. They contribute their findings to investor awareness of global warming and suggest creating policies that lower the information gap between the public and researchers. Alessi, Ossola, and Panzica (2021) find evidence of a negative green premium for European stocks. Kempa et al. (2021) find evidence that renewable energy companies (they did not investigate electric utilities) had higher costs of debt than conventional energy companies before 2007. However, after 2007 the opposite was true. They propose regulatory pressure and lower risk premia as explanations for this change. Bernardini et al. (2021) investigated the equity returns of an unbalanced panel of EEU, ranging from four firms in 2006 to 12 firms in 2016. They extended traditional factor models with a low-carbon minus high-carbon factor and found a risk premium for low-carbon EEU. Dorfleitner et al. (2021) found evidence of a green bond premium that rises given external evaluation of the greenness of the use of proceeds. In, Park, and Monk (2019) found evidence that carbon-efficient US equities outperformed their carbon-inefficient counterparts from 2005 to 2015. Whereas, Bolton and Kacperczyk (2021) discovered a carbon premium in the cross-section of US stock returns from 2005 to 2017 suggesting that investors expect to be compensated for carbon risk as measured by carbon emissions. They contribute the results from In, Park, and Monk (2019) to "the market inefficiency hypothesis" while arguing that the carbon premium is a newer phenomenon and is therefore only recently observable. Görgen, Nerlinger, and Wilkens (2020) investigate a cross section of global equities and find evidence of a brown minus green factor. However, they do not find evidence of a carbon risk premium attributing this result to mispricing by investors. Basse Mama and Mandaroux (2022) investigate firms regulated by the EU emissions trading system and find a valuation discount related to carbon emissions. Given the mixed results found in previous literature, we investigate the possibility of a carbon risk premium in the returns of European electric utilities. We expect investors to account for carbon risk in our sample of EEU due to the previously mentioned sizeable contribution to global warming (climate change is assumably more important in calculating the risk involved in owning utilities than, e.g., a software company or the whole market). Furthermore, the EU has strengthened its commitment to achieving a carbon neutral economy over the last 17 years since the introduction of the EU ETS and has emphasized the need for low-carbon and renewable electricity. Therefore, the authors believe investors have lowered their risk perception for renewable and low-carbon EEU (compared to conventional and high-carbon EEU) over time due to regulatory change and greater climate awareness.

We test the following four hypotheses. First, this paper furthers the carbon premium research by substantially extending the sample size and model employed by Bernardini et al. (2021) while investigating a different time period and portfolios. Furthermore, based on the carbon emissions premium found by Bolton and Kacperczyk (2021) we hypothesize that a carbon intensity premium exists for EEU (**H1**). Second, this paper investigates the possibility of an energy mix premium, building off the results of Koch and Bassen (2013). We expect investors to assign EEU with a higher proportion of conventional energy sources a higher level of risk. We, therefore, hypothesize that there is an energy mix premium for EEU (**H2**). Third, due to the regulatory pressure to decarbonize electricity production, we hypothesize that portfolios of taxonomy orientated and renewable energy[14] EEU outperform their counterparts,

[13] Generally attributed to Sharpe (1964).

[14] This paper defines renewable energy according to Article 2 paragraph 1 of Directive (EU) 2018/2001 (2018) "wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy,

non-orientated and conventional energy respectively (**H3**). This third hypothesis, at first, seems to contradict some of the previous literature including the theory presented by Pástor et al. (2021) which finds that climate risk leads to lower costs of capital for green stocks and therefore an underperformance compared to brown stocks in a state of market equilibrium. While our outperformance hypothesis might seem counterintuitive, since lower costs of capital should lead to lower portfolio returns in the long-term, the short-term effect[15] of lowering capital costs results in rising stock prices. In other words, if green stocks are viewed as becoming less risky due to a tightening of climate policies, investors will expect a lower return to hold such stocks which results in rising prices until the price reflects the lower level of risk. Hence, the short-term outperformance of green stocks compared to brown stocks.[16] We do, however, theoretically expect green stocks to underperform brown stocks in a market equilibrium as outlined by Pástor et al. (2021). Fourth, Matsumura et al. (2014) found that a penalty was imposed on the firm value of firms in the S&P500 that did not report carbon emissions data. This penalty can be seen as an adjustment to the expected returns of non-reporting companies, i.e., a risk premium for not reporting relevant information to investors. Dhaliwal et al. (2011) find that the initiation of a CSR report leads to a lower cost of capital in the following year. Therefore, we also hypothesize: taxonomy orientated and non-orientated portfolios outperform a non-reporting portfolio (**H4**).

Data and model

Data

We created a list of all listed companies from the 27 countries currently in the EU, the United Kingdom and Switzerland with the Standard Industrial Classification codes 4911 and 4924. This list comprised 79 companies. We then read annual reports from the companies to determine if they primarily produce electricity. After removing companies from the list that do not primarily produce electricity, we had 47 electric utility companies. According to *eurostat*, the *Department for Business, Energy & Industrial Strategy* and the *Swiss Federal Office of Energy* the 27 EU countries, the United Kingdom and Switzerland generated 3,046 TWh[17] of electricity in 2020. The 47 EEU on our list produced 2,845 TWh of electricity in 2020. We are, therefore, confident that our 47 EEU are representative of the European electric utilities market. The carbon emission and electricity production data necessary for our analysis was not available for every company in each year due to a lack of reporting. Therefore, we have an unbalanced panel of 47 EEU with 114 monthly returns from July 2011 to December 2020 for a total of 5,046 observations. A list of the 47 EEU can be found in Table 5 in the appendix.

Dependent variables

The quality and quantity of available carbon emission and electricity production data from various data providers was insufficient to test our hypotheses. First, the main sustainability data providers did not have the source of energy used in electricity production for the EEU in our time series. Second, the carbon intensity of said electricity production was only available for a portion of the time series and is often estimated by data providers. Third, Busch et al. (2020) find carbon data reported in corporate reports to be more consistent than estimated data, for which estimation methods are fairly untransparent. Consequently, we hand-collected the data required for our analysis from annual and sustainability reports from 2010 to 2019 which provided us with the unique dataset necessary for the evaluation of our hypotheses. We gathered the carbon intensity (gCO_2e/kWh) of total electricity produced at the company level and the percentage of company level electricity production from each source of energy for the 47 EEU.

The taxonomy specifies that all types of electricity production should adhere to a threshold based on lifetime emissions at the activity level of 100 gCO2e/kWh of electricity produced (European Commission, 2021a). However, previous non-financial reporting did not provide this information, therefore, this paper could only apply the carbon intensity threshold to a company's aggregated carbon intensity from electricity production and not the lifetime intensity of individual power plants. We were unable to determine actual taxonomy conformity since past reporting does not provide the necessary information. We therefore chose to use proxies for taxonomy conformity, i.e., aggregate firm-level CO_2 intensity instead of lifetime plant-level CO_2 intensity. Hence, the portfolios are constructed based on taxonomy orientation and not taxonomy conformity. Furthermore, the EC had not

Footnote 14 (continued)

tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas."

[15] We believe that there were multiple short-term adjustments during our analysis due to the increasing regulatory pressure to decarbonize and green electricity production during the last decade.

[16] For a more detailed explanation of expected and realized returns in a sustainability context, please refer to Cornell (2021).

[17] Statistical Office of the European Union (2022); Department for Business, Energy & Industrial Strategy (2021); Swiss Federal Office of Energy (2021).

Table 1 Overview of variables

Variables		Description
Dependent	n	
T	*11*	A portfolio of taxonomy orientated EEU, i.e., companies emitting ≤100 gCO_2e/kWh from aggregated electricity production and no nuclear energy production.
NT	*27*	A portfolio of non-taxonomy orientated EEU, i.e., emitting >100 gCO_2e/kWh from aggregated electricity production or nuclear energy production.
NR	*9*	A portfolio of non-reporting EEU, i.e., companies that do not provide enough information to determine the carbon intensity of electricity production and potential nuclear involvement.
RE_{80}	*9*	A portfolio of EEU with a percentage of energy from renewable sources in the top quintile.
RE_{60}	*8*	A portfolio of EEU with a percentage of energy from renewable sources in the fourth quintile.
RE_{40}	*8*	A portfolio of EEU with a percentage of energy from renewable sources in the third quintile.
RE_{20}	*8*	A portfolio of EEU with a percentage of energy from renewable sources in the second quintile.
RE_{0}	*9*	A portfolio of EEU with a percentage of energy from renewable sources in the bottom quintile, i.e. conventional energy.
Independent		
mkt	*47*	The market return: the return of a value weighted portfolio of all EEU.
rf		The risk-free rate: the monthly return on the 3-month EURIBOR.
smb	*47*	The size factor: the small minus big factor was calculated using the methodology from Fama & French (1993) and the EEU.
hml	*28*	The value factor: the high minus low factor was calculated using the methodology from Fama & French (1993) and the EEU.
lmh	*22*	The carbon intensity factor: the low-carbon intensity minus high-carbon intensity factor was calculated using the methodology from Fama & French (1993) for their hml factor and the EEU.
rmc	*26*	The energy mix factor: the renewable minus conventional energy factor was calculated using the methodology from Fama & French (1993) for their hml factor and the EEU.
coal		A proxy for the return of coal in euros: the ICE Rotterdam continuous coal future.
gas		A proxy for the return of gas in euros: the ICE Endex Dutch TTF gas future
oil		A proxy for the return of oil in euros: the Europe Brent Spot FOB future.

This table includes the description of the variables used in the regressions and the number (*n*) of companies in each portfolio/factor for 2020. Financial data was downloaded from Refinitiv's Datastream. Equity returns are based on local currencies Megginson et al. (2000) and are adjusted for splits and dividends. The *smb*, *hml*, *lmh* and *rmc* factors used information from December of t-1 for portfolio construction at the end of June in year t. The market capitalization for the portfolio weights is the closing market capitalization in euros at the end of June in each year of portfolio construction. Portfolios were reconstructed and rebalanced yearly at the end of June. Returns are monthly and continuous. Since the portfoliosused to construct the *hml*, *lmh* and *rmc* factors are based on 2x3 portfolios which excluded the middle portfolios, 28 is the maximum possible number of companies in these factors.

made a definitive decision about the inclusion/exclusion of nuclear energy as a clean source of energy during our sample period. The EC ruled against the recommendations of the Technical expert group on sustainable finance (TEG) by including nuclear power as a potentially taxonomy conform and green source of electricity (TEG, 2020). However, this unexpected decision came after the sample period for this research ended. Therefore, we believe investors assumed the EC would follow the recommendation of the TEG by excluding nuclear power from taxonomy conform electricity. Furthermore, European countries have been split about whether nuclear power can be considered sustainable and future orientated for over a decade. This division could have created uncertainty for investors which could have influenced their investment decisions. We ultimately chose to exclude nuclear from the taxonomy orientated portfolio since this decision came after the period under consideration. Therefore, we excluded any company involved in the production of electricity from nuclear sources from the taxonomy orientated portfolio. These definition and aforementioned data problems are not unique to our portfolio construction but rather would have also been problematic for portfolio managers. Therefore, we believe the use of a proxy for taxonomy conformity to be justified.

Value-weighted discrete monthly returns are used to create dynamic portfolios[18] with a 6-month lag from the time the carbon intensity and energy mix data was published to ensure that the information would have been available during portfolio construction. Five portfolios were constructed based on quintile breaks in the percentage of renewable energy in the energy mix of the 47 EEU. Three additional portfolios were created based on the taxonomy orientation

[18] Portfolios were reconstructed on a yearly basis at the end of June i.e., a company assigned to one portfolio in a given year *t* could be assigned to a different portfolio in *t+1*.

Table 2 Descriptive statistics

Dependent Variables	RE_{80}	T	RE_{60}	RE_{40}	NT	NR	RE_0	RE_{20}
Mean	0.0135	0.0128	0.0112	0.0087	0.0048	0.0031	0.0015	0.0010
Median	0.0170	0.0163	0.0115	0.0104	0.0083	0.0002	0.0065	0.0034
Std. dev.	0.0537	0.0562	0.0527	0.0542	0.0486	0.0603	0.0619	0.0467
Independent Variables	mkt-rf	rmc	smb	hml	lmh	coal	gas	oil
Mean	0.0087	0.0060	0.0025	−0.0010	−0.0016	−0.0036	−0.0053	−0.0054
Median	0.0110	0.0101	0.0024	0.0074	−0.0044	−0.0029	−0.0035	−0.0035
Std. dev.	0.0515	0.0545	0.0317	0.0402	0.0496	0.0746	0.0392	0.1587

All returns are monthly, continuous and sorted by the mean. Dependent variable returns are net the *rf* rate. A one-sided (greater than) Wilcoxon test was used to test the significance of the differences between the portfolio means. Significance is denoted by: * $p < 0.1$, ** $p < 0.05$ and *** $p < 0.01$ and given in parenthesis. Only portfolios with significant differences are listed. RE_{80}•RE_{20} (***), RE_{80}•RE_0 (**), RE_{80}•NT (**); RE_{60}•RE_{20} (***), RE_{60}•RE_0(***), RE_{60}•NT (*), RE_{60}•NR (*); RE_{40}•RE_{20} (***), RE_{40}•RE_0 (*), RE_{40}•NT (**); T•RE_{20} (***), T•RE_0 (**) and T•NT (**).

of the 47 EEU. Table 1 provides an explanation of the eight portfolios.

Independent variables

The *smb* and *hml* factors from Fama and French (1993) are calculated from the monthly returns of the EEU. Their three-factor model is extended with proxies for *oil*, *gas* and *coal* returns since Henriques and Sadorsky (2008) found the oil price to have a significant impact on the stock price of alternative energy companies. Furthermore, gas and coal constitute a significant portion of the energy mix for EEU and fluctuating prices for these commodities might influence their performance. Two further factors based on the carbon intensity of the EEU and the level of renewable energy in their energy mix extend the model.

The carbon intensity factor was created following the methodology from Fama and French (1993) in calculating their *hml* factor. More specifically, six portfolios were created according to median breaks in size (market capitalization) and 30/40/30 percentile-breaks[19] in carbon intensity (gCO2e/kWh). The two middle (40 percentile-break) portfolios were excluded from the factor calculation. Discrete value weighted monthly returns were calculated for each of the following four portfolios: small/low-carbon intensity, big/low-carbon intensity, small/high-carbon intensity and big/high-carbon intensity. The following formula was then used to calculate a low minus high-carbon intensity factor

$$lmh = 0.5(SL + BL) - 0.5(SH + BH)$$

where *SL* is the discrete monthly return of the small/low-carbon intensity portfolio, *BL* is the discrete monthly return of the big/low-carbon intensity portfolio, *SH* is the discrete monthly return of the small/high-carbon intensity portfolio, *BH* is the discrete monthly return of the big/high-carbon intensity portfolio and *lmh* is the low-carbon intensity minus high-carbon intensity factor. The log returns of the *lmh* factor were used for the regression analysis. Our second factor is the renewable minus conventional energy (*rmc*) factor. The methodology used to create the *lmh* factor was also used to create the *rmc* factor. The only difference is that the *rmc* factor is based on the percentage of renewable energy a company produces instead of carbon intensity, i.e., breaks in the percentage of renewable energy produced at 30/40/30 percentiles. The *lmh* and *rmc* factors are used to investigate the possibility of carbon risk and energy mix risk premia, respectively, among EEU. All factors are presented in Table 1.

Models

This paper uses an ordinary least squares methodology in regressing the following three models to test our hypotheses. Model 1 is the three-factor model from Fama and French (1993)

$$r_{i,t} - rf_t = \alpha_i + \beta_{i,mkt}\left(mkt_t - rf_t\right) + \beta_{i,smb}\, smb_t + \beta_{i,hml}\, hml_t + \varepsilon_{i,t} \quad (1)$$

where the dependent variable is the return of each of the previously mentioned portfolios in excess of the risk-free rate (*rf*), *mkt* is the return of the entire EEU sample, *smb* is the size factor, *hml* is the value factor and ε is the error term. Model 2 extends the first model with proxies for the returns on *oil*, *gas* and *coal*

[19] We also could have used, e.g., 20/60/20 percentile breaks. However, we chose to follow the methodology laid out in Fama and French (1993) when calculating the factors used in our analysis. Our results are generally robust to other percentile breaks.

$$r_{i,t} - rf_t = \alpha_i + \beta_{i,mkt}\left(mkt_t - rf_t\right) + \beta_{i,smb}\, smb_t + \beta_{i,hml}\, hml_t + \beta_{i,oil}\, oil_t + \beta_{i,gas}\, gas_t + \beta_{i,coal}\, coal_t +_{i,t} \tag{2}$$

Model 3 extends the second model with *rmc* (the energy mix factor) and *lmh* (the carbon intensity factor)

$$r_{i,t} - rf_t = \alpha_i + \beta_{i,mkt}\left(mkt_t - rf_t\right) + \beta_{i,smb}\, smb_t + \beta_{i,hml}\, hml_t + \beta_{i,oil}\, oil_t + \beta_{i,gas}\, gas_t + \beta_{i,coal}\, coal_t + \beta_{i,rmc}\, rmc_t + \beta_{i,lmh}\, lmh_t + \varepsilon_{i,t} \tag{3}$$

Empirical findings

Descriptive statistics

Table 2 provides the mean, median and standard deviation (Std. dev.) for the eight portfolios and the eight factors presented in Table 1. Further descriptive statistics for each of the dependent portfolios for the year 2020 are given in Table 6 in the appendix. The portfolio of companies with the largest percentage of renewable energy in the mix has the highest mean return followed by the portfolio of taxonomy orientated companies. We interpret this finding as the first indication that **H3** is correct. The mean portfolio return for each of the five portfolios based on the energy mix decreases as the amount of renewable energy produced decreases (the order of the fourth and fifth quintile portfolios are exchanged). The mean return of the non-orientated and non-reporting portfolios are both lower than that of the taxonomy orientated portfolio pointing to a possible confirmation of **H4**. The *mkt-rf* factor notably has the highest mean among the factors. Furthermore, the *hml* and *lmh* factors and commodity proxies are all negative in the mean.

Regression results

First, each of the eight portfolios' monthly returns was regressed against a six-factor model to determine if the three-factor model from Fama and French (1993) and the commodity proxies adequately explain these returns. *Panel A of* Table 3 presents these results. While the alphas from NT, RE_{80} and RE_{20} are significant (possibly hinting that some excess return is not accounted for), the other five dependent variables have insignificant alphas. The adjusted R-squared for all regressions is fairly low, except for the NT regression, further pointing to the possibility that the model could be improved. We then extended the six-factor model with the *rmc* and *hml* factors and regressed each of the eight portfolios against this model. The results of these regressions can be seen in *Panel B of* Table 3. The adjusted R-squared for each of the regressions increased compared to those in *Panel A of* Table 3. Furthermore, the *rmc* factor has the expected sign and is significant in all the regressions except for the RE_{40} and RE_{20} portfolios. The *lmh* factor is significant in half of the regressions: T, RE_{80}, RE_{40} and RE_0. These results point to the existence of both carbon (confirming **H1**) and energy mix premia (confirming **H2**) for the majority of the EEU portfolios.

The next step in this analysis addresses **H3** and **H4**. Difference portfolios are computed to investigate if taxonomy orientated EEU outperform both non-orientated EEU (T-NT) and non-reporting EEU (T-NR). We also examine whether non-orientated EEU outperform non-reporting EEU (NT-NR) and if renewable EEU outperform conventional EEU (RE_{80}-RE_0). *Panel A of* Table 4 presents the results of the difference portfolio regressions based on the three-factor model. The size beta is significant for all four difference portfolios and plays the largest role. Both taxonomy orientated and renewable energy EEU tend to be smaller than their non-taxonomy orientated and conventional counterparts. Non-reporting EEU are smaller than taxonomy orientated EEU which is in line with Drempetic et al. (2020). Most other factors do not significantly explain the difference portfolios. However, the alphas for three of the four portfolios are significant, demonstrating an outperformance of the taxonomy orientated portfolio over both the non-orientated and non-reporting portfolio. Furthermore, the renewable energy portfolio outperforms the conventional energy portfolio.

In *Panel B of* Table 4, the taxonomy orientated and renewable energy portfolios still outperform the non-orientated and conventional energy portfolios respectively. Furthermore, the taxonomy orientated and non-orientated portfolios have less exposure to the coal beta than the non-reporting portfolio, which could indicate that non-reporting companies might have a higher level of coal in the energy mix. The renewable energy portfolio has less exposure to the oil beta than the conventional energy portfolio. *Panel C of* Table 4 presents the results of the regressions with the complete model.

The outperformance of taxonomy orientated companies compared to non-orientated companies is confirmed but the alphas of the two other difference portfolios are insignificant. The *rmc* beta is significant and positive for all four difference portfolios and the *lmh* beta is significant and positive for three of the difference portfolios. The taxonomy orientated portfolio also has less exposure to the oil beta than the non-orientated and non-reporting portfolios. The adjusted R-squared for each difference portfolio is also much higher than in *Panel A* or *B*, which lends strength to the explanatory power of the carbon intensity and energy mix factors. In summary, we find evidence confirming **H3:** a taxonomy orientated portfolio outperforms a non-orientated portfolio (statistically significant in all 3 models) and a renewable energy portfolio outperforms a conventional

Table 3 Full sample regressions

	T	NT	NR	RE_{80}	RE_{60}	RE_{40}	RE_{20}	RE_{0}
Panel A: Six-Factor Model								
α	0.0063	−0.0027 *	−0.0053	0.0069 *	0.0029	−0.0007	−0.0051 *	−0.0052
	(0.0038)	(0.0014)	(0.0046)	(0.0039)	(0.0031)	(0.0029)	(0.0027)	(0.0033)
mkt-rf	0.8202 ***	0.8455 ***	0.6671 ***	0.7868 ***	0.8374 ***	1.0152 ***	0.6697 ***	0.7936 ***
	(0.083)	(0.0326)	(0.099)	(0.0957)	(0.0734)	(0.0701)	(0.0481)	(0.0862)
smb	0.3259 **	−0.1174 **	0.8017 ***	0.4541 **	0.1998	0.2422 **	−0.1619 **	−0.2489 **
	(0.1559)	(0.0502)	(0.1137)	(0.1821)	(0.1212)	(0.1059)	(0.079)	(0.1011)
hml	0.1037	−0.0195	0.2844	0.0671	0.1534	−0.0025	0.0026	−0.011
	(0.1079)	(0.036)	(0.1901)	(0.1)	(0.0946)	(0.065)	(0.0679)	(0.0718)
oil	0.0186	0.0265 *	0.0542 *	0.0023	−0.0013	−0.0323 **	0.0395 **	0.1077 ***
	(0.0269)	(0.015)	(0.0284)	(0.0195)	(0.0173)	(0.0142)	(0.0188)	(0.0376)
gas	0.0006	0.0134	−0.0237	−0.0306	−0.0227	−0.0813	0.0755	0.0837
	(0.1023)	(0.0409)	(0.1125)	(0.101)	(0.079)	(0.0746)	(0.0665)	(0.1114)
coal	−0.067	−0.0293	0.1338 *	−0.0359	−0.0812 *	0.007	−0.0189	−0.0763 *
	(0.0603)	(0.0186)	(0.077)	(0.0561)	(0.0418)	(0.0442)	(0.0307)	(0.0433)
Adj. R^2	0.514	0.922	0.421	0.465	0.613	0.762	0.727	0.721
Panel B: Eight-Factor Model								
α	0.0043	−0.0022 *	−0.0025	0.0049	0.0006	−0.0002	−0.0046 *	−0.004
	(0.0033)	(0.0013)	(0.004)	(0.0031)	(0.0028)	(0.0029)	(0.0027)	(0.0033)
mkt-rf	0.8998 ***	0.8292 ***	0.6058 ***	0.8693 ***	0.8787 ***	0.9952 ***	0.6566 ***	0.7849 ***
	(0.0792)	(0.029)	(0.0954)	(0.0781)	(0.074)	(0.0706)	(0.047)	(0.0892)
smb	0.3877 ***	−0.1261 ***	0.8036 ***	0.5257 ***	0.1821 *	0.2236 **	−0.1644 **	−0.2162 **
	(0.1048)	(0.0417)	(0.1055)	(0.1269)	(0.1063)	(0.0999)	(0.0762)	(0.0924)
hml	0.1814 **	−0.0354	0.2258	0.1479 **	0.1925 **	−0.0221	−0.01	−0.0184
	(0.0749)	(0.0354)	(0.1602)	(0.0666)	(0.0897)	(0.0722)	(0.0651)	(0.0751)
rmc	0.2145 ***	−0.0617 **	−0.3867 ***	0.1886 ***	0.3345 ***	−0.0407	−0.07	−0.1996 ***
	(0.0794)	(0.0256)	(0.0946)	(0.069)	(0.0769)	(0.0626)	(0.046)	(0.0668)
lmh	0.3452 ***	−0.0504	−0.0118	0.3966 ***	−0.0766	−0.1023 *	−0.017	0.1647 *
	(0.0838)	(0.0306)	(0.0964)	(0.0802)	(0.0699)	(0.0615)	(0.0617)	(0.0858)
oil	0.0011	0.0301 **	0.0671 ***	−0.016	−0.0099	−0.0278 *	0.0423 **	0.1091 ***
	(0.0218)	(0.0151)	(0.0229)	(0.0171)	(0.0141)	(0.0143)	(0.0191)	(0.0352)
gas	−0.0713	0.0224	−0.0395	−0.1159	0.0116	−0.0589	0.0762	0.0349
	(0.0907)	(0.0396)	(0.0931)	(0.0847)	(0.0764)	(0.0638)	(0.0678)	(0.11)
coal	−0.0132	−0.0389 **	0.1103 *	0.0226	−0.0714 *	−0.0076	−0.0249	−0.0678
	(0.0425)	(0.0169)	(0.0564)	(0.0435)	(0.0373)	(0.0406)	(0.0323)	(0.043)
Adj. R^2	0.702	0.932	0.536	0.691	0.706	0.771	0.73	0.74

Heteroskedasticity and autocorrelation corrected standard errors are in parentheses. R^2 has been adjusted for degrees of freedom. All regressions are highly significant. Significance is denoted by: * $p < 0.1$, $^{**}p < 0.05$ and $^{***}p < 0.01$

energy portfolio (statistically significant in models 1 and 2). However, we can only partially confirm **H4** based on the results of the regression with model 1 where the taxonomy-orientated portfolio significantly outperforms the non-reporting portfolio. The other models do not confirm **H4** and the outperformance of the non-orientated over the non-reporting portfolio cannot be confirmed. This evidence reinforces the findings in the descriptive statistics that taxonomy orientated and renewable EEU outperform their counterparts, non-orientated and conventional energy respectively. This outperformance is at least partially due to carbon and energy mix premia. In short, the market seems to reward greener EEU with lower costs of capital as evidenced by the higher prices commanded by the green EEU in our time series.

Robustness checks

Since the self-constructed Fama and French factors used to test our hypothesis were formed from a relatively small

Table 4 Difference portfolio regressions

	T-NT	T-NR	NT-NR	RE_{80}-RE_0
Panel A: Three-Factor Model				
α	0.0087 *	0.0101 *	0.0011	0.0119 *
	(0.0044)	(0.006)	(0.0044)	(0.0062)
mkt-rf	−0.0289	0.1016	0.1295	−0.1296
	(0.0532)	(0.1069)	(0.1072)	(0.1568)
smb	0.4673 ***	−0.3925 *	−0.8881 ***	0.6391 ***
	(0.1642)	(0.2119)	(0.086)	(0.1982)
hml	0.1088	−0.2287	−0.3345 *	0.0985
	(0.1272)	(0.2435)	(0.1863)	(0.1557)
Adj. R^2	0.098	0.039	0.319	0.151
Panel B: Six−Factor Model				
α	0.0085 *	0.0093	0.0006	0.0099 *
	(0.0043)	(0.0062)	(0.0042)	(0.0053)
mkt-rf	−0.0218	0.1364	0.1553	0.0101
	(0.0904)	(0.1161)	(0.0954)	(0.1331)
smb	0.4561 **	−0.4447 **	−0.9308 ***	0.7220 ***
	(0.1822)	(0.2142)	(0.0958)	(0.2001)
hml	0.122	−0.1666	−0.2845	0.061
	(0.1263)	(0.2422)	(0.1737)	(0.1283)
oil	−0.0059	−0.0409	−0.0321	−0.0828 **
	(0.0235)	(0.0463)	(0.0358)	(0.0317)
gas	−0.0149	0.0371	0.0381	−0.1465
	(0.1097)	(0.1674)	(0.1191)	(0.1652)
coal	−0.0398	−0.2118 *	−0.1708 **	0.0392
	(0.0681)	(0.1141)	(0.0805)	(0.0735)
Adj. R^2	0.079	0.076	0.356	0.197
Panel C: Eight−Factor Model				
α	0.0059 *	0.0044	-0.0018	0.0067
	(0.003)	(0.0044)	(0.004)	(0.0044)
mkt-rf	0.0756	0.2775 **	0.1992 **	0.103
	(0.0749)	(0.1093)	(0.1003)	(0.1214)
smb	0.5283 ***	−0.3846 ***	−0.9437 ***	0.7651 ***
	(0.1056)	(0.1457)	(0.1038)	(0.1459)
hml	0.2171 **	−0.03	−0.2429	0.151
	(0.086)	(0.1406)	(0.1529)	(0.103)
rmc	0.2782 ***	0.6024 ***	0.3284 ***	0.3809 ***
	(0.0829)	(0.1264)	(0.1061)	(0.0938)
lmh	0.4047 ***	0.3578 ***	−0.0507	0.2533 **
	(0.0864)	(0.1099)	(0.1011)	(0.123)
oil	−0.0274 *	−0.0714 *	−0.0413	−0.1030 ***
	(0.0146)	(0.0388)	(0.0344)	(0.03)
gas	−0.0978	−0.019	0.0659	−0.1884
	(0.0803)	(0.12)	(0.1053)	(0.1327)
coal	0.0248	−0.1344 *	−0.1582 **	0.0913
	(0.0483)	(0.0712)	(0.0631)	(0.0648)
Adj. R^2	0.525	0.512	0.434	0.448

Heteroskedasticity and autocorrelation corrected standard errors are in parentheses. R^2 has been adjusted for degrees of freedom. All regressions are significant. Significance is denoted by: *$p < 0.1$, ** $p < 0.05$ and *** $p < 0.01$

sample, they could be fairly dependent on the returns of a few firms which could lead to a self-fulfillment bias. We, therefore, ran regressions with the European *mkt, rf*, *smb* and *hml* factors from Kenneth R. French's website[20] to check the robustness of our results. Furthermore, we used different breaks in the percentage of renewable energy a company produces and its carbon intensity when creating the portfolios for the *rmc* and *lmh* factors to ensure that the factors are robust to different breaks. The results are largely consistent with the findings presented in *Panel B of* Table 3 *and Panel C of* Table 4. Finally, we regressed the *rmc* and *lmh* factors against the other 6 factors and found these other factors do not significantly explain our two factors. Table 7 in the appendix presents the correlations between the 8 factors. The results of the robustness checks lead us to believe that our results are not dependent on: self-fulfilling regressions due to sample size; the chosen breaks when constructing the factors; and that *rmc* and *lmh* cannot be explained by the other factors used in our analysis.

Conclusion

This paper investigates whether taxonomy orientated and renewable energy EEU portfolios outperform their counterparts while exploring the possibility of carbon and energy mix premia. We investigated a different timeseries than Bernardini et al. (2021) while considerably expanding their sample. We find a positive low-carbon premium (confirming **H1**) for portfolios of taxonomy orientated and renewable energy EEU. Furthermore, we find evidence of an energy mix premium for a more representative sample and updated timeseries thereby confirming the robustness of the earlier results from Koch and Bassen (2013). We can confirm **H2**, i.e., the level of renewables in the energy mix positively affects the returns of the taxonomy orientated and renewable energy portfolios while negatively affecting the non-orientated, non-reporting and conventional energy portfolios. The taxonomy orientated and renewable energy portfolios outperformed their counterparts confirming **H3**. This outperformance can be partially explained by the carbon and energy mix premia. This outperformance agrees with the findings from In, Park, and Monk (2019) pertaining to carbon efficient and inefficient US equities while not directly contradicting Bolton and Kacperczyk (2021), who do not find evidence of a high-carbon intensity premium but rather a carbon emissions premium for their cross-section of US stocks. Furthermore, they investigated the effect of carbon emissions on the stock returns of US companies from 71 GIC 6 industries whereas we investigated the performance of portfolios of European electric utility companies. Next, we find that a taxonomy orientated portfolio outperforms a non-reporting portfolio in agreement with the results from Matsumura et al. (2014) pertaining to the S&P500. However, the non-orientated portfolio does not significantly outperform the non-reporting portfolio. Hence, we can only partially confirm **H4**. This finding could be interpreted as evidence that investors value non-financial reporting from companies with a higher sustainability performance. Our results provide evidence that investors could have anticipated regulations, similar to the taxonomy, pertaining to carbon intensity and that they could have acknowledged certain risks associated with global warming and the transition to a carbon neutral system of energy production.

Our results are important for investors, EEU and regulators. Investors could potentially profit from creating portfolios based on taxonomy orientation and the percentage of renewables used in the energy mix depending on how close we are to a market equilibrium a la Pástor et al. (2021). European electric utilities could potentially profit from lower costs of capital if they either raise the level of renewables in their energy mix or align their energy production to the taxonomy. If these companies then report their climate friendly electricity production, they could be rewarded with lower costs of capital. Finally, Regulators can see that the markets are pricing in carbon and energy mix risks which could be a result of their signaling/regulations. Further research should test this paper's findings in a few years once data granularity allows for the creation of portfolios based on taxonomy conform energy production at the activity level. We were only able to determine a company's aggregate level of CO_2 intensity, due to insufficient reporting, and not the CO_2 intensity of the company's individual power plants. Furthermore, it would be interesting to test the effects of the unexpected inclusion of nuclear energy in the taxonomy by repeating our study with portfolios sorted along the newest taxonomy definitions. An event study could also examine the effects of including nuclear and gas in the taxonomy on the returns of nuclear and gas EEU. Lastly, the identified carbon and energy mix risk premia should be both tested on a longer time series of EEU and calculated for both other regions and industries that are significantly affected by climate change regulation to ensure that the results of this paper are not attributable to a short-term market anomaly.

Appendix

Tables 5, 6, 7.

[20] https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

Table 5 European electric utilities

Name	ISIN	Name	ISIN
A2A	IT0001233417	ERG	IT0001157020
ACEA	IT0001207098	EVN	AT0000741053
ALBIOMA	FR0000060402	FALCK RENEWABLES	IT0003198790
ALERION CLEAN POWER	IT0004720733	FORTUM	FI0009007132
ATHENA INVESTMENTS	DK0010240514	GOOD ENERGY	GB0033600353
AUDAX RENOVABLES	ES0136463017	HERA	IT0001250932
BKW	CH0130293662	IBERDROLA	ES0144580Y14
CENTRICA	GB00B033F229	IREN	IT0003027817
CEZ	CZ0005112300	MVV ENERGIE	DE000A0H52F5
CONTOURGLOBAL	GB00BF448H58	NATURGY ENERGY	ES0116870314
DRAX GROUP	GB00B1VNSX38	ORSTED	DK0060094928
E.ON	DE000ENAG999	PGE	PLPGER000010
EDF	FR0010242511	POLENERGIA	PLPLSEP00013
EDP	PTEDP0AM0009	PUBLIC POWER	GRS434003000
EDP RENOVAVEIS	ES0127797019	ROMANDE ENERGIE	CH0025607331
ENBW	DE0005220008	RWE	DE0007037129
ENCAVIS	DE0006095003	S. N. NUCLEARELECT	ROSNNEACNOR8
ENDESA	ES0130670112	SSE	GB0007908733
ENEA	PLENEA000013	TAURON POLSKA	PLTAURN00011
ENEL	IT0003128367	TERNA ENERGY	GRS496003005
ENERGA	PLENERG00022	UNIPER SE	DE000UNSE018
ENERGIEDIENST	CH0039651184	VERBUND	AT0000746409
ENERGIEKONTOR	DE0005313506	ZE PAK SE	PLZEPAK00012
ENGIE	FR0010208488		

The table provides the names and ISINs for the 47 EEU

Table 6 Descriptive statistics for the dependent portfolios in 2020

	Unit	RE_{80}	RE_{60}	RE_{40}	RE_{20}	RE_0	T	NT	NR
Portfolio MC	Bn. €	17.20	76.07	173.26	102.21	72.35	67.15	395.58	8.60
Average MC	Bn. €	1.91	9.51	21.66	12.78	8.04	6.10	14.65	0.96
BTM	Ratio	0.88	0.43	0.54	0.86	1.33	0.47	0.76	2.37
CO_2 intensity	gCO_2e/kwh	0	122.66	239.77	300.23	312.01	45.02	270.79	NA
Renewables	%	100	80.53	40.69	21.55	10.43	90.52	31.85	9.10
Nuclear	%	0	0	13.93	41.10	43.07	0	27.16	NA
n		9	8	8	8	9	11	27	9

This table provides descriptive statistics for each portfolio in 2020. **T** is the portfolio of taxonomy orientated EEU. **NT** is the portfolio of non-taxonomy orientated EEU. **NR** is the portfolio of non-reporting EEU. $\mathbf{RE_{80}}$, $\mathbf{RE_{60}}$, $\mathbf{RE_{40}}$, $\mathbf{RE_{20}}$ and $\mathbf{RE_0}$ are portfolios with a percentage of energy from renewable sources in the top, 4th, 3rd, 2nd and bottom quintile respectively. *Portfolio MC* is the total market capitalization for the entire portfolio, *Average MC* is the average market capitalization of the firms in the portfolio and *BTM* is the weighted average book to market ratio for the portfolio. The *CO_2 intensity* is provided, *Renewables* is the percentage of electricity produced from renewable sources, *Nuclear* is the percentage of electricity produced from nuclear sources and *n* indicates the number of companies in the respective portfolio for 2020

Table 7 Factor correlations

	mkt-rf	smb	hml	rmc	lmh	oil	gas	coal
mkt-rf	1.00							
smb	−0.39***	1.00						
hml	0.08	−0.11	1.00					
rmc	−0.12	0.08	−0.11	1.00				
lmh	−0.05	−0.03	−0.11	0.53***	1.00			
oil	0.38***	−0.03	−0.03	0.03	0.12	1.00		
gas	0.19*	−0.09	0.07	−0.06	0.13	0.43***	1.00	
coal	0.03	−0.20*	0.23*	−0.13	−0.08	0.09	0.46***	1.00

This table presents the Pearson correlations between the 8 factors used in our model. Significance is denoted by: * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$

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Declarations

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Ethical approval The study complies to ethical standards.

References

Alessi, Lucia, Elisa Ossola, and Roberto Panzica. 2021. What Greenium matters in the stock market? The role of greenhouse gas emissions and environmental disclosures. *Journal of Financial Stability* 54: 100869. https://doi.org/10.1016/j.jfs.2021.100869.

Amihud, Yakov. 2002. Illiquidity and stock returns: cross-section and time-series effects. *Journal of Financial Markets* 5 (1): 31–56. https://doi.org/10.1016/S1386-4181(01)00024-6.

Mama, Basse, Houdou, and Rahel Mandaroux. 2022. Do investors care about carbon emissions under the european environmental policy?. *Business Strategy and the Environment* 31 (1): 268–283. https://doi.org/10.1002/bse.2886.

Bernardini, Enrico, Johnny Di Giampaolo, Ivan Faiella, and Riccardo Poli. 2021. The impact of carbon risk on stock returns: evidence from the European electric utilities. *Journal of Sustainable Finance & Investment* 11 (1): 1–26. https://doi.org/10.1080/20430795.2019.1569445.

Bolton, Patrick, and Marcin Kacperczyk. 2021. Do Investors care about carbon risk?. *Journal of Financial Economics* 142 (2): 517–549. https://doi.org/10.1016/j.jfineco.2021.05.008.

Busch, Timo, Matthew Johnson, and Thomas Pioch. 2020. Corporate carbon performance data: quo Vadis?. *Journal of Industrial Ecology* 26 (1): 350–363. https://doi.org/10.1111/jiec.13008.

Carhart, Mark M. 1997. On persistence in mutual fund performance. *The Journal of Finance* 52 (1): 57–82. https://doi.org/10.1111/j.1540-6261.1997.tb03808.x.

Choi, Darwin, Zhenyu Gao, and Wenxi Jiang. 2020. Attention to global warming. *The Review of Financial Studies* 33 (3): 1112–1145. https://doi.org/10.1093/rfs/hhz086.

Cornell, Bradford. 2021. ESG preferences, risk and return. *European Financial Management* 27 (1): 12–19. https://doi.org/10.1111/eufm.12295.

Department for Business, Energy & Industrial Strategy. 2021. "UK Energy in Brief." Unpublished manuscript, last modified August 05, 2022. www.gov.uk/government/statistics/uk-energy-in-brief-2021.

Dhaliwal, Dan S., Oliver Z. Li, Albert Tsang, and Yong G. Yang. 2011. Voluntary nonfinancial disclosure and the cost of equity capital: The initiation of corporate social responsibility reporting. *The Accounting Review* 86 (1): 59–100. https://doi.org/10.2308/accr.00000005.

"Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 Establishing a Scheme for Greenhouse Gas Emission Allowance Trading Within the Community and Amending Council Directive 96/61/EC (Text with EEA Relevance)." 2003. *OJ L 275/32*.

"Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC." 2009. *OJ L 140/16*.

"Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 Amending Directive 2003/87/EC so as to Improve and Extend the Greenhouse Gas Emission Allowance Trading Scheme of the Community." 2009. *OJ L 140/16*.

"Directive 2018/2001/EC of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources." 2018. *OJ L 328/82*.

Dorfleitner, Gregor, Sebastian Utz, and Rongxin Zhang. 2021. The pricing of green bonds: external reviews and the shades of green. *Review of Managerial Science*. https://doi.org/10.1007/s11846-021-00458-9.

Drempetic, Samuel, Christian Klein, and Bernhard Zwergel. 2020. The influence of firm size on the ESG score: corporate sustainability ratings under review. *Journal of Business Ethics* 167 (2): 333–360. https://doi.org/10.1007/s10551-019-04164-1.

European Commission (2011). "Communication from the Comission to the European Parliament, the Council, the European Economic and Social Comittee and the Committee of the Regions: Energy Roadmap 2050." COM (2011) 885 final.

———. 2014. "Communication from the Comission to the European Parliament, the Council, the European Economic and Social Comittee and the Committee of the Regions: A Policy Framework for Climate and Energy in the Period from 2020 to 2030." COM(2014) 15 final.

———. 2020a. "Commission Staff Working Document Impact Assessment Accompanying the Document Communication from the Comission to the European Parliament, the Council, the European Economic and Social Comittee and the Committee of the Regions: Stepping up Europe's 2030 Climate Ambition Investing in a Climate-Neutral Future for the Benefit of Our People." SWD(2020)176.

———. 2020b. "Communication from the Comission to the European Parliament, the Council, the European Economic and Social Comittee and the Committee of the Regions: Stepping up Europe's 2030 Climate Ambition Investing in a Climate-Neutral Future for the Benefit of Our People." COM(2020b) 562 final.

———. 2021a. "Commission Delegated Regulation(EU) …/… Supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by Establishing the Technical Screening Criteria for Determining the Conditions Under Which an Economic Activity Qualifies as Contributing Substantially to Climate Change Mitigation or Climate Change Adaptation and for Determining Whether That Economic Activity Causes No Significant Harm to Any of the Other Environmental Objectives." C(2021) 2800 final.

———. 2021b. "Communication from the Comission to the European Parliament, the Council, the European Economic and Social Comittee and the Committee of the Regions: Strategy for Financing the Transition to a Sustainable Economy." COM(2021b) 390 final.

Fama, Eugene F. 1970. Efficient capital markets: a review of theory and empirical work. *The Journal of Finance* 25 (2): 383. https://doi.org/10.2307/2325486.

Fama, Eugene F., and Kenneth R. French. 1993. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics* 33 (1): 3–56. https://doi.org/10.1016/0304-405X(93)90023-5.

Fama, Eugene F., and Kenneth R. French. 2007. Disagreement, tastes, and asset prices. *Journal of Financial Economics* 83 (3): 667–689. https://doi.org/10.1016/j.jfineco.2006.01.003.

Fama, Eugene F., and Kenneth R. French. 2015. A Five-factor asset pricing model. *Journal of Financial Economics* 116 (1): 1–22. https://doi.org/10.1016/j.jfineco.2014.10.010.

Görgen, Maximilian., Jacob Andrea, Nerlinger Martin, Riordan Ryan, Rohleder Martin, and Wilkens, Marco. 2020. Carbon Risk. Available at SSRN: https://ssrn.com/abstract=2930897 or https://doi.org/10.2139/ssrn.2930897

Gupta, Surbhi, and Anil K. Sharma. 2022. Evolution of infrastructure as an asset class: A systematic literature review and thematic analysis. *Journal of Asset Management* 23 (3): 173–200. https://doi.org/10.1057/s41260-022-00255-3.

Henriques, Irene, and Perry Sadorsky. 2008. Oil prices and the stock prices of alternative energy companies. *Energy Economics* 30 (3): 998–1010. https://doi.org/10.1016/j.eneco.2007.11.001.

Hübel, Benjamin, and Hendrik Scholz. 2020. Integrating sustainability risks in asset management: The role of ESG exposures and ESG ratings. *Journal of Asset Management* 21 (1): 52–69. https://doi.org/10.1057/s41260-019-00139-z.

In, Soh Y., Ki Y. Park, and Ashby Monk. 2019. *Is 'Being Green' Rewarded in the Market? An Empirical Investigation of Decarbonization and Stock Returns*.

Kempa, Karol, Ulf Moslener, and Oliver Schenker. 2021. The cost of debt of renewable and non-renewable energy firms. *Nature Energy* 6 (2): 135–142. https://doi.org/10.1038/s41560-020-00745-x.

Koch, Nicolas, and Alexander Bassen. 2013. Valuing the carbon exposure of European utilities. The role of fuel mix, permit allocation and replacement investments. *Energy Economics* 36: 431–443. https://doi.org/10.1016/j.eneco.2012.09.019.

Matsumura, Ella M., Rachna Prakash, and Sandra C. Vera-Muñoz. 2014. Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review* 89 (2): 695–724. https://doi.org/10.2308/accr-50629.

Megginson, William L., Robert C. Nash, Jeffry M. Netter, and Adam L. Schwartz. 2000. The long-run return to investors in share issue privatization. *Financial Management* 29 (1): 67. https://doi.org/10.2307/3666362.

Monasterolo, Irene, and Luca de Angelis. 2020. Blind to Carbon Risk? An analysis of stock market reaction to the Paris agreement. *Ecological Economics* 170: 106571. https://doi.org/10.1016/j.ecolecon.2019.106571.

Novy-Marx, Robert. 2013. The other side of value: The gross profitability premium. *Journal of Financial Economics* 108 (1): 1–28. https://doi.org/10.1016/j.jfineco.2013.01.003.

Oestreich, A.M., and Ilias Tsiakas. 2015. Carbon emissions and stock returns: Evidence from the EU emissions trading scheme. *Journal of Banking & Finance* 58: 294–308. https://doi.org/10.1016/j.jbankfin.2015.05.005.

Pástor, Ľuboš, Robert F. Stambaugh, and Lucian A. Taylor. 2021. Sustainable investing in Equilibrium. *Journal of Financial Economics* 142 (2): 550–571. https://doi.org/10.1016/j.jfineco.2020.12.011.

Sharpe, William F. 1964. Capital asset prices: A theory of market equilibrium under conditions of risk*. *The Journal of Finance* 19 (3): 425–442. https://doi.org/10.1111/j.1540-6261.1964.tb02865.x.

Statistical Office of the European Union. 2022. *Gross and Net Production of Electricity and Derived Heat by Type of Plant and Operator: Eurostat (Nrg_ind_peh):* eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_production,_consumption_and_market_overview#Electricity_generation.

Stotz, Olaf. 2021. Expected and realized returns on stocks with high- and low-ESG exposure. *Journal of Asset Management* 22 (2): 133–150. https://doi.org/10.1057/s41260-020-00203-z.

Swiss Federal Office of Energy. 2021. "Gesamte Erzeugung Und Abgabe Elektrischer Energie in Der Schweiz." Unpublished manuscript, last modified August 05, 2022. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/electricity-statistics.html.

Technical expert group on sustainable finance. 2020. "Technical Annex to the TEG Final Report on the EU Taxonomy." https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/200309-sustainable-finance-teg-final-report-taxonomy-annexes_en.pdf. Accessed February 24, 2022.

United Nations. 2015. "Paris Agreement." https://unfccc.int/sites/default/files/english_paris_agreement.pdf. Accessed November 10, 2021

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