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Green energy jumping grey hurdles

On the effect of renewable energy generation on the cost of capital in the energy sector

Author: J.R. Neijzen
Student number: 388068
Thesis supervisor: Dr. R. Huisman
Second Assessor: V.C. Stet
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1. Introduction

For decades fossil fuels have satisfied most of human's energy requirements. Through the utilization of these fossil fuels, the energy sector is currently the most polluting sector and accounts for two-thirds of global CO2 emissions (IEA, 2019a). The electricity generation industry is the worst herein, 30% of global emissions being from coal-fired electricity generation only (IEA, 2019b). These emissions emerge with renewables only accounting for 26% of global electricity generation in 2018 (IEA, 2019c). Although fossil fuels are still dominant, two main drawbacks have been distinguished. The first is that fossil fuels heavily pollute the atmosphere upon combustion and accounts for approximately 80% of all manmade carbon emissions (EUROSTAT, 2019). The second one is that the amount of remaining reserves is finite and depleting, with about 50 years of oil and gas and 150 years of coal left (BP, 2018, 2019; WCA, 2019). As global demand for energy is also expected to rise by 50% between 2018 and 2050, the energy sector experiences extreme pressure to transition to clean and renewable energy resources (EIA, 2019). To align countries in the necessity of developing sustainable energy sources, multiple international environmental agreements have been made. Out of these, the adoption of the Kyoto Protocol in 1997 was the first major international effort against climate change with 191 countries backing the agreement (United Nations, 1997). The Kyoto Protocol, aimed at reducing greenhouse gas emissions, is legally binding and sets emission reduction targets for developed countries. Its purpose was not achieved however, with developing countries including China being excluded from adhering to the targets and the US and Russia not signing the agreement. On 12 December 2015 the Paris Agreement was presented. The aim of this agreement is to keep the global temperature rise below 2 °C above pre-industrial levels and attempt to limit the rise to 1.5 °C (United Nations, 2015). The Paris Agreement brought all nations together into a common cause against climate change for the first time. This agreement resulted in increased awareness and urged governments to come up with concrete measures to promote the reduction of emissions. This included providing incentives, regulations and more investments in renewable energy. As a response, businesses have made steps in adhering to sustainability through incorporating it into their strategy, measuring their carbon footprint and reducing emissions. Larger companies not only work on their own footprint, but also require for their suppliers to join their initiatives (Apple, 2019).

If the National Determined Contributions (NDCs) under the Paris Agreement are met, renewable energy resources play an indispensable role and has the potential to capture two-thirds of total power demand by 2050 (IRENA, 2019b). Electricity is becoming increasingly important herein, with a share of 20% of global energy in 2018 and rising to 50% in 2050 (IRENA, 2019b). Electricity consumption is to double in size because of this, driven primarily by powering over a billion electric vehicles and an increased use for heat generation in buildings. Renewables are expected to provide over 60% of global electricity by 2050, with variable renewables such as solar and wind making up for almost 50% of total electricity (Bloomberg, 2019). This requires for renewable energy generation to expand seven-fold (IRENA, 2019b). In terms of sustainability is green energy estimated to, conjoined with an increase in energy efficiency, account for 90% of the required CO2 emission reductions to reach a sustainable and decarbonized energy sector as proposed by the Paris Agreement (IRENA, 2019a). Although the required technologies are not developed yet, advancements are made with investments in renewable power generation reaching 304 billion USD in 2018 and are expected to reach a cumulative total of 10 trillion USD in 2040 (IEA, 2019e). This resulted in some renewable resources already generating energy at lower costs than conventional sources (IRENA, 2019c).

Despite this positive attention and the necessity of renewable energy, the adoption rate of these resources by companies in the energy sector is still relatively low. Governments act and try to incentivize investments in renewable energy by the private sector but are often ill-informed about one of the most important decision inputs: the cost of capital (Donovan and Corbishley, 2016). The cost of capital is the return that a firm's shareholders and creditors require for the capital they provide. This return that shareholders and creditors require is associated with the risk of a project or firm, in which greater risks result in a higher cost of capital. The profits of a firm are discounted by this cost of capital and only when a company earns a return greater than this, value is created for the shareholders (Modigliani and Miller, 1958). To account for this discount rate, companies often set a hurdle rate for their investments that is higher than the required cost of capital (Antle and Eppen, 1985; Donovan, 2015). As a result, it is important for firms to know their cost of capital and what the impact of their projects and initiatives is on this. The complication is that estimating the cost of capital a priori is inherently difficult for firms, financial investors and policymakers due to information asymmetries, heterogeneity of investment methodologies and the relative immaturity of the renewable energy sector (Donovan and Corbishley, 2016).

This difficulty in estimating the cost of capital results in companies perceiving renewable energy projects as not profitable enough compared to fossil fuel projects, while the difference in cost of capital is unknown to them. This leads to opposing views in regard to the difference in cost of capital, in which on one hand Donovan (2015) argues that fossil fuel projects are associated with a higher inherent risk profile. This higher risk profile is due to risks including those related to the exploration of potential reserves, environmental spillage crises and risks regarding price fluctuations. Donovan (2015) states that the higher returns for fossil fuel projects are as compensation for the higher risks and cost of capital of those projects. Furthermore, this results in renewable projects being perceived as less attractive, although they enjoy lower risks and can therefore have less return as compensation without sacrificing profitability (Donovan, 2015). Other studies, including that of De Jager et al. (2008), indicate that the discount rate of renewables is not necessarily lower than that of their fossil counterparts. The authors argue that renewables are also submit to risks, including capital-intensity risks, risk associated with intermittency, technological risks, and more that all have substantial effects on the risk adjusted discount rate (De Jager et al., 2008; Hu et al., 2018). A third group of studies state that while a fixed-cost clean energy assets can cost more when assessed on a stand-alone basis, the returns from these projects should be weakly correlated to that of fossil fuels and other asset classes as renewable energy projects have stable cashflows and no fuel price risk (Awerbuch and Yang, 2007; Donovan and Corbishley, 2016). To energy firms and financial investors, this generates diversification benefits that could translate into extraordinarily low discount rates as renewable energy have the potential to be zero beta, meaning returns that are unaffected by market swings, investments (Donovan and Corbishley, 2016). To incentivize both energy companies and investors, and to accelerate the adoption of renewable energy, research into the impact of renewables and their potential benefits on the cost of capital is crucial. This knowledge can help both energy firms and financial investors to make more informed decisions on renewable projects while correctly taking into account the cost of capital. Although this research largely fails to find a clear relationship between generating renewable energy and the cost of capital for energy firms, evidence has been found that producing green energy decreased the beta for medium size firms. There is also evidence that firms, especially electric utility firms, tend to use leverage to finance their renewable initiatives.

The setup of this paper is as follows. The literature overview in Chapter 2 provides an overview of the literature regarding the cost of capital and risk profile of renewable resources, the underlying theories regarding why firms do environmental initiatives, and how this research is going to fill a not previously examined gap in literature. Next, the hypotheses with which the research question will be answered are forlumated in Chapter 3. The hypotheses are examined with the methodology explained in Chapter 4. The methodology is used on the dataset on which information is presented in Chapter 5. Subsequently, the results are presented in chapter 6 and the conclusion, limitations and recommendations are found in chapter 7.

2. Literature on the risk of renewables and causal theories

This chapter consists of multiple parts. First of all, I give an overview on how the cost of capital measures the risks of renewable energy and why this is relevant for the renewable transition. Second, the risks of renewable energy are identified and how these compare to fossil fuels. After, I discuss how incorporating renewable energy into a firm's strategy fits into the theories regarding competitive advantage. The chapter concludes with identifying the research question.

2.1 Cost of capital as incentive to adopt renewables

As stated before, the cost of capital is the return that is required by the shareholders and creditors for the capital they provided. Because those shareholders and creditors want a higher return when their investment faces higher risks, the cost of capital shows how the capital market assesses the intrinsic value and riskiness of a firm's cashflows. More specifically, the cost of capital reflects how both the tangible and intangible benefits and risks are perceived by the shareholders and creditors in a risk-return tradeoff. For a company to adopt and commit to renewable energy initiatives, it is important to know how their shareholders and creditors perceive the risks associated with these energy sources, as this determines the profitability and attractiveness of these initiatives for a given return. This can be illustrated with the following scenarios: In the first case, a firm adopts renewable energy and while the market perceives this as a more efficient resource utilization, they don't perceive this as a change in riskiness. This results in the cost of capital remaining unchanged (Sharfman and Fernando, 2008). In the second case the firm is seen as less risky and the cost of capital of the firm decreases. In this case the profits of the firm are discounted by a lesser percentage, because their shareholders and creditors are satisfied with less return as compensation for the risk they faced, and the firm enjoys more profit for the same amount of return. Consequently, if the higher cost of capital more than overcomes the cost of transitioning, environmentally concerned firms will transition to obtain a more favorable cost of capital (Heinkel et al., 2001). This means that the cost of capital could be the manner through which the capital market can stimulate firms to adopt green energy initiatives. To be able to determine how the riskiness of renewables is perceived, the benefits and risks of renewables compared to fossil fuels must be known.

2.2 The upside of renewables

Decreasing the risks associated with the cashflows of a firm are as important as increasing returns for providers of capital. Knowledge of the relative risks of renewable energy sources compared to that of fossil fuels is key to knowing what the change in cost of capital will be. To know the relative risks of renewables versus fossil fuels, it is important to map the benefits and risks of renewables compared to fossil fuels. Starting with the advantages, they can be divided into two categories: the environmental and the economic benefits of renewable resources.

To start with the environmental benefits, one of the most important advantage is that green energy sources are inexhaustible, as the sun does not stop shining and the wind does not stop blowing. This is a large benefit compared to fossil fuels, where the risks of depletion of reserves are substantial with a finite amount of reserves left. What this inexhaustability of green energy sources translates into for companies, is that renewables do not have any risks associated with the exploration of new reserves. These exploration costs are often substantial and accompanied by the risk that the reserve is too small or of a bad quality. A second environmental benefit is that green energy sources do not expel harmful emissions that damage the atmosphere or cause thermal pollution. The advantage this has for companies is that there are no risks related to new or increased policies on carbon emissions or risks associated with environmental spillage crises (Donovan, 2015).

An economic benefit is that renewable projects have lower risk of additional operational expenses on equipment. The technologies used in these projects require less maintenance because most of the equipment do not have moving parts that wear out and need to be replaced (Donovan, 2015; Schleicher-Tappeser, 2012; Winkler and Mavhungu, 2002). This means that apart from the initial costs of installing the necessary equipment, there are less risks regarding sudden defects that cause revenue to decline. Sustainable energy sources also don't have vulnerabilities regarding price fluctuations. The absence of these fluctuations is achieved through the introduction of feed-in tariffs, which are long-term contracts with renewable energy producers that provides price certainty to accelerate green energy investments (Couture and Gagnon, 2010). The feed-in tariffs, combined with the lesser risk on operational expenses and the inexhausability of green resources together result in stable cashflows that do not correlate with macro economic conditions and are unaffected by market swings (Donovan and Corbishley, 2016). This zero-beta correlation entices both firms and investors because they ensure some cashflow stability even when a recession takes place. Lastly, an increasing amount of renewable energy generation results in firms that are more robust against vulnerabilities to political instabilities, trade disputes and embargoes from fossil fuel exporting countries. The importance of this can be illustrated when, for instance, large parts of Europe experience shortfalls if Russia was to stop exporting fossil fuels.

2.3 The downside of renewables

In their studies, Castillo and Gayme (2014); De Jager et al. (2008); Gowrisankaran et al. (2016); Hu et al. (2018); Kaenzig and Wüstenhagen (2010) identify various barriers that increases the risk of green resources and hinder renewable energy integration. The risk associated with these barriers can very well cause the discount rate of renewables to not necessarily be lower than that of their fossil counterparts and include capital-intensity risks, risk associated with intermittency, technological risks, risk concerning the electricity grid and regulatory risks regarding the continuity of existing support schemes and the lack of long term policy visibility (De Jager et al., 2008; Hu et al., 2018). Of these risks, only the first two are inherent to renewable energy sources, the others are all related to the immaturity of the renewable energy sector. Financial theory states that unsystematic risks such as these should not be included in the cost of capital. Recent studies, however, conclude that risk premiums for unsystematic risks are often added to the cost of capital in practice (Jagannathan et al., 2016). The abovementioned risks are adressed more specifically below.

Capital-intensity risk originates from renewables having a different cost structure compared to traditional energy sources, with higher upfront capital expenditures but lower operational and maintenance costs (Kaenzig and Wüstenhagen, 2010; Winkler and Mavhungu, 2002). These higher upfront costs skew the investment profiles of renewable projects to the early part of the lifecycle, increasing the risk of being unable to acquire a decent profit and reduce the economic appeal of these projects (Donovan, 2015). Compared to renewables, conventional energy sources have their costs spread out more evenly over the project's lifecycle.

The intermittency risk comes from renewables being inherently intermittent, as solar panels generate less energy at night and some days are windier than others (Gowrisankaran et al., 2016). Intermittency imposes operational risk as there the capacity and output of renewables. Storage systems are being developed as solution for this intermittency, but these are not yet competitive for longer term durations (Lazard, 2019).

To harness power from green energy sources and to reach its full potential, research and technological advances are needed. This is due to hydro, onshore wind, solar photovoltaic and bioenergy currently being the only competitive renewables compared to conventional energy sources (IRENA, 2019c). As renewable energy thus requires new technological developments that have not yet been done, shareholders and creditors perceive this as riskier investments which impact the cost of capital accordingly. This is also the conclusion of the study of Henriques and Sadorsky (2008), in which they observed that the stock price and beta of renewable energy companies behaves more like that of risky tech companies than that of energy companies.

Besides renewable technology, developments are also required in modifying electricity grids to be able to stabilize fluctuations in the inherent variability and intermittency of renewable energy generation. Current grid infrastructure will be unable to maintain reliability as a larger number of less predictable energy sources are incorporated into the system (Castillo and Gayme, 2014; Sueyoshi and Goto, 2009). As modifying the grid requires very large investments and takes multiple years to finish, this could mean that these hurdles do not enhance the financial performance of utilities at once but rather over the long-term, again inducing risks on renewable investments. This is seen in the study of Ruggiero and Lehkonen (2017), who examined electricity generation utilities and found a negative correlation between renewable energy production and short as well as long-term performance. Sueyoshi and Goto (2009) likewise investigated electricity generating utilities and indicated that there was a negative relation between short-term environmental and financial performance.

The risk regarding the continuity of existing support schemes and the lack of long-term policy visibility is, together with the extent to which companies adhere to renewable initiatives, highly dependable on country specific government incentives and emission prices. This is supported by the study of Johnstone et al. (2010) who found that governmental environmental policies have a significant effect on the amount of renewable technology patents. More specifically, the authors concluded that different policies are effective on different renewable sources. In this, broad-based policies such as energy certificates induce innovations on technologies that are close to competitive with fossil fuels while targeted subsidies such as feed-in tariffs induce innovations on more expensive technologies such as solar power. Looking at which region has the most stringent governmental policies and incentives, Europe is the most ambitious continent with strict targets and binding legislation regarding renewable energy. More specifically, countries in the European Union (EU) set a 32% share of renewable energy as target for 2030 (EC, naa). Their target is to have a net-zero greenhouse gas emission by 2050 and while this doesn't include a target for renewable energy, the share of renewables has to increase dramatically in order to achieve net-zero emissions EC (nab). Compared to the EU, other regions are less ambitious regarding renewable energy. For instance, the United States have no nation-wide target for renewable energy, although each state has adopted its own renewable energy targets to still try and adhere to the renewable energy transition. These policies vary significantly among states, with New York, California and the District of Columbia having respective 2030/2032 targets of 60%, 70% and 100% respectively (Barbose, 2019). China, with a 27% emission share in 2018 the largest CO_2 emitter globally, has far less stringent policies regarding renewable energy (Statista, 2019). China's targets according to the Paris Agreement includes increasing the share of non-fossil energy to 20% (CAT, na; den Elzen et al., 2019).

2.4 Renewable energy and competitive advantage

The natural-resource-based view (NRBV) proposed by Hart (1995) complements the resource-based view of Wernerfelt (1984) that competitive advantage results from the combined utilization of a firm's unique, hard-to-imitate resources together with its distinctive internal capabilities, by including the natural environment into this framework. By integrating the environment Hart (1995) believed that environmentally sustainable activities improved the internal capabilities of firms which improved their competitive advantage. These capabilities can be divided in three main sources: pollution prevention, product stewardship and sustainability, that result in improved efficiency, cost reductions and strategic advantages in changing business environments (Aragón-Correa and Sharma, 2003; Hart, 1995). Building on this theory, Hart and Dowell (2011) specifically indicate that clean technologies such as renewable energy projects result in firms building new competencies and position themselves for competitive advantage in evolving industries. Another theory that supports this view of clean technologies is the instrumental stakeholder theory (Donaldson and Preston, 1995; Jones, 1995). According to this theory, meeting and satisfying stakeholder demands provides firms with competitive advantages, enhancing amongst others its efficiency in the adaptation to external demands (Orlitzky et al., 2003). As stakeholders are concerned about the environment, environmental initiatives can be seen as attempts in which firms try to meet these concerns (Buysse and Verbeke, 2003). Meeting these demands results in advantages including the attraction and retainment of high-quality employees, better relations with suppliers and consumers, more favorable terms with creditors and a reduction in perceived risk by investors (Bauer and Hann, 2010; Reinhardt, 1999; Sharfman and Fernando, 2008). More recent studies argue that the NRBV and the instrumental stakeholder theory should be seen as complementary approaches in which stakeholder pressure provide firms with incentive to introduce processes such as renewable initiatives to acquire competitive advantages and reduce the risk perceived by investors (Endrikat et al., 2014; Hart and Dowell, 2011).

2.5 Prior studies and the research question

Looking at to what extend prior research has covered the effect of renewable energy on the cost of capital in the energy sector, the IEA (2019d) assembled a sample of the 25 power companies with the highest amount of solar and wind capacity and the 25 top oil & gas producing companies in 2018 to compare the cost of capital change over the years 2006 to 2018. The IEA found that the cost of equity as well as the cost of debt decreased steadily over time for the renewable energy companies. On the other hand, the cost of equity of the oil & gas companies increased during the same time while the cost of debt declined until 2015, after which it steadily increased as well. While this study provides an indication of the effect of renewable energy, this effect is not isolated and could be influenced by other factors. Other studies that examined the cost of capital in the energy sector are that of Bassen et al. (2006); Connors and Silva-Gao (2008); Gao and Connors (2011) who investigated electric utility companies and Gonenc and Scholtens (2017) who looked at oil & gas companies. More specifically, Bassen et al. (2006) established that corporate responsibility was associated with a lower cost of capital. Connors and Silva-Gao (2008) found that high TRI emissions correlated with a higher cost of equity. Gao and Connors (2011) later found that better environmental performance reduces the volatility of the firm's cash flows, decreases potential bankruptcy costs and increases debt capacity. Gonenc and Scholtens (2017) proved that both environmental and financial outperformance can be associated with a reduced beta and thus cost of equity for oil & gas firms. These studies, however, did not look at the effect of renewable energy specifically. When looking for studies that do measure the impact of renewable energy on the cost of capital of companies in the energy sector, there appears to be a void in literature while this is critical in aiding companies in transitioning towards renewable energy resources.

This research aims to adress this gap in knowledge by shedding light on the impact of renewable energy generation on the cost of capital of companies in the energy sector. By looking at the impact on the cost of capital, information is revealed about how the capital markets perceive the risk associated with investing and developing green energy products versus that fossil fuels products. For instance, when renewable energy projects generate a lower return than fossil fuel projects, but the cost of capital decreased to a certain extend as well, the total effect of renewable energy could still be better than that of fossil fuel energy. In fact, if renewable energy does lower a firm's cost of capital, focusing on returns only to indicate financial performance will be misleading (Gregory et al., 2014). Research into the changes in the cost of capital can help both energy firms and financial investors to make more informed decisions on renewable projects while correctly taking into account the cost of capital, thereby contributing to a more efficient energy transition. The corresponding research question is:

What is the effect of generating more renewable energy on the cost of capital of companies within the energy sector?

3. Hypotheses development

To answer and resolve the research question, the effect of renewable energy generation is investigated on the cost of capital through examining public electricity generating utilities and public oil & gas companies globally. The cost of capital is the return that a firm's equity investors and bondholders demand for the capital they provided. The amount of return required by the investors corresponds with the risk of their investments. The cost of capital consists of the weighted average cost of equity and cost of debt. To determine the effect on the different dynamics of the cost of capital, the cost of capital is split into the cost of equity, cost of debt and amount of financial leverage. To be able to make more precise inferences about the effect on the cost of capital, this research also analyses which industry group the effect is most pronounced, whether the effect is stronger in more recent years and if the impact is more pronounced in regions with more ambitious policies and targets concerning green energy.

The first hypothesis concerns how the shareholders and equity market perceive green energy generation by looking at changes in the cost of equity. According to the Capital Asset Pricing Model (CAPM), a change in the cost of equity is most likely due to a changed systematic risk and manifests itself in the equity beta (Feldman et al., 1996). If a company's renewable activities are perceived as more robust against systematic or market risk, the company's beta and consequently cost of equity will be reduced as a result. Prior research into the cost of equity shows that that firms with a more proactive environmental management and performance strategy experience a strong and significant reduction in their beta and thus cost of equity capital (Feldman et al., 1996). Firms with higher environmental risk management have a lower cost of equity as more investors want to acquire the stock of less environmentally risky firms, according to Sharfman and Fernando (2008). Gonenc and Scholtens (2017) confirmed this, while investigating oil & gas firms and the authors argue that both environmental and financial outperformance can be associated with a reduced beta. Chava (2014) analyzed non-financial firms from the KLD database and found an increased cost of equity and debt at firms with environmental concerns; Gupta (2018) investigated the link between environmental sustainability and the cost of equity of firms using an environmental performance index and also found a negative correlation; El Ghoul et al. (2018) contended that environmental responsibility is linked to a lower cost of equity capital while analyzing manufacturing firms. Consequently, my expectation is that renewable energy generation reduces the cost of equity by lowering the unlevered beta. The corresponding null and alternative hypotheses are:

Null hypothesis 1: More renewable energy generation is not associated with a reduction in the non-leveraged equity beta of companies in the energy sector

and

Alternative hypothesis 1: More renewable energy generation is associated with a reduction in the non-leveraged equity beta of companies in the energy sector.

The other component of the cost of capital is the cost of debt. The cost of debt incurred by a company is based on how the capital market perceives the company's risk of default. The greater the uncertainty of the future activities, the lower the assessed credit quality and the higher the cost of debt and interest rates to company has to pay when acquiring new debt (Sharfman and Fernando, 2008). For instance, if the capital market perceives generating more green energy as an activity that lessens the risk of default, the credit rating of the company will be higher and cost of debt lower. This results in the company having to pay lower interest rates on loans it acquires. The cost of debt is especially important to the power sector, as debt is their primary means for raising capital (Bassen et al., 2006). This results in power companies being under more scrutiny from bondholders, regulatory agencies and investors and analysts (Filbeck et al., 1997). Prior studies show that firms with a proactive environmental engagement measures experienced a lower cost of debt, and that a firm's efforts to reduce its impact on climate change and air pollution through clean energy are particularly associated with lower bond spreads (Bauer and Hann, 2010). Eliwa et al. (2019) confirms this by suggesting that the market rewards ESG practices by reducing the cost of debt, with the environmental dimension having the largest impact on this. On the other hand, Sharfman and Fernando (2008) indicated that higher environmental risk management is associated with an increased cost of debt, although they attribute this to an increase in leverage. These studies, especially the first two, suggest that a higher environmental performance may be associated with a lower cost of debt, meaning this could be true as well for renewable energy. Therefore, the next null and alternative hypotheses are:

Null hypothesis 2: More renewable energy generation is not associated with a reduction in the cost of debt of companies in the energy sector

and

Alternative hypothesis 2: More renewable energy generation is associated with a reduction in the cost of debt of companies in the energy sector.

The last hypothesis is focused on the capital structure of the companies with the amount of financial leverage being examined. If a company's cost of debt is reduced because of green energy, it may choose to take advantage of this by increasing its level of debt (Sharfman and Fernando, 2008). Because interest payable is deducted from the pre-tax income, a higher amount of leverage can shield the company from taxation. This tax shield is an advantage that reduces a company's after-tax cost of capital. Note that more financial leverage also increases the cost of equity and cost of debt of a company as creditors are paid before shareholders, which decreases the chance that shareholders get paid, and the default rate increases as more leverage means the firm is obliged to pay more interest. As renewable projects are capital intensive and firms want to take full advantage of its tax shield and reduced cost of debt, renewable energy generation can result in higher amounts of financial leverage of companies in the energy sector. Prior research by Gao and Connors (2011) found evidence with electric utilities that better environmental performance results in higher amounts of leverage and that capital intensity played a role in explaining this. Sharfman and Fernando (2008) stated that if a company improves its environmental risk, the debt market is willing to provide more debt financing. These beforementioned statements, together with Bassen et al. (2006) arguing that debt is the primary mean of raising capital for the power sector, provides the notion that firms favor leverage as for financing green energy projects. This results in the next null and alternative hypotheses being:

Null hypothesis 3: Renewable energy generation is not associated with an increase in financial leverage of companies in the energy sector

and

Alternative hypothesis 3: Renewable energy generation is associated with an increase in financial leverage of companies in the energy sector.

Although electric utilities, multiline utilities and oil & gas companies are all part of the energy sector, there are substantial differences in the environmental-financial performance relationship along fossil fuel firms in different industries (Gonenc and Scholtens, 2017). To be able to provide useful information to companies in the industries with which they can work, the differences in effect is also analyzed between those industries to determine which companies have the strongest incentive to adopt renewable energy projects. Prior studies comparing the 3 industries in relation with renewable energy do not exist, although Pätäri et al. (2012) investigated both electric utilities and oil & gas companies and indicated that sustainability-driven companies were better in controlling costs and generating higher profits. The oil & gas industry is known as one of the worst polluting industries and increasingly generating green energy can possibly be seen as a transition in which the company transfers from the oil & gas industry towards the less infamous electric generating utility or renewable energy industry. The expectation is that this transition will be met with a reduced cost of capital as the firms move away from the very risky oil & gas industry. Consequently, the next null and alternative hypotheses are:

Null hypothesis 4: The impact of generating more renewable energy is not more pronounced on oil & gas than on multiline- or electric utility companies

and

Alternative hypothesis 4: The impact of generating more renewable energy is more pronounced on oil & gas than on multiline- or electric utility companies.

Over the years, as public awareness for environmental sustainability increased, external pressure to adhere to sustainability increased as well. Socially Responsible Investment (SRI) funds emerged that invests in companies engaged in social and environmental efforts only, avoiding companies engaged in tobacco, weapons and fossil fuels. SRI has become increasingly important as the investment philosophy has been adopted by a growing number of institutional investors (Sparkes and Cowton, 2004). Consequently, sustainability is often a requirement nowadays, with 49% of the assets under management in Europe being sustainable invested in 2018 and 26% of total assets under management being sustainable invested in the US (GSIA, 2019). This leads to stocks of fossil fuel firms being held by fewer investors, which results in lower stock prices and a higher cost of capital (Heinkel et al., 2001). The authors also showed how green investors only invest in green and renewable companies, while non-green investors are indifferent and invests in both types of companies. This results in green companies having more investors, higher share price and a lower cost of capital than non-green, fossil fuel companies. Heinkel et al. (2001) also found that the cost of capital of environmentally concerned firms increased with the trend in ethical investing. Chava (2014) also indicated that with the trend in SRI, creditors likewise progressively started to consider environmental issues in their lending decisions, thereby increasing the interest rates and cost of debt for environmental concerned companies. The results of these studies in combination with the increase in efficiency of clean technologies over the years, generally seem to imply that the effects of sustainable initiatives such as renewable energy could be more pronounced over time, resulting in the following null and alternative hypotheses:

Null hypothesis 5: The positive effects of renewable energy generations are not more pronounced in recent years

and

Alternative hypothesis 5: The positive effects of renewable energy generations are more pronounced in recent years.

The extent to which companies adhere to renewable initiatives is highly dependable on country specific government incentives. This is supported by studies including that of Ata (2015); Hu et al. (2018); Johnstone et al. (2010). More specifically, Ata (2015) demonstrated that renewable policy instruments stimulate renewable investments by reducing the risks for investors, resulting in larger deployment mechanisms. Hu et al. (2018) describes various barriers to renewable investments that can only be overcome by policymakers, thereby stressing the importance of policymakers in combatting market failure and the competitiveness of fossil fuels. In their research, Johnstone et al. (2010) found that governmental environmental policies have a significant effect on the amount of renewable technology patents and that different policy schemes emphasized investments in different kind of renewable technologies. With the next hypothesis I want to test whether more stringent policies make for an accelerated adoption of green energy, in which the expectation is that companies from Europe experience the most profound effects. The last null and alternative hypotheses therefore are:

Null hypothesis 6: The impact of generating more renewable energy is not most pronounced for companies in Europe

and

Alternative hypothesis 6: The impact of generating more renewable energy is most pronounced for companies in Europe.

4. Methodology

In this section the methodology used to examine the hypotheses will be described. The first section contains information about the dependent, independent and the control variables used in this research. After, the choice in estimation technique is discussed with which the panel data will be analyzed. This chapter ends with the specification of the models used to examine the hypotheses.

4.1 Variables

This section discusses which variables are used as the dependent, independent and control variables.

4.1.1 Dependent Variables

To examine and answer the hypotheses, different dependent variables are introduced to the models corresponding with the hypotheses. The impact on the cost of equity is determined by the CAPM (Lintner, 1965; Sharpe, 1964). Following the CAPM, the risk-free rate and the expected market return can both not be influenced by a firm. This results in the equity beta being the only component of the cost of equity that differs between firms and can be influenced by firms. The formula for computing the equity beta is as follows:

$$\beta_{equity} = \frac{Covariance(r_{market}, r_{stock})}{Variance(r_{market})} \tag{4.1}$$

The equity beta is obtained from Thomson Reuters DataStream, computed using a 5-year monthly frequency. The local equity indices were used as proxy for the market return in calculating the beta. Using the MSCI World Index was preferred, but this gave betas ranging from -7 to 25, which seemed unrealistic. After obtaining the equity beta from the database, the beta is unlevered because the equity beta is influenced by the capital structure of a firm, which would make it less effective when comparing across companies. Unlevering the beta is done, as the name indicates, by using the Hamada equation to 'unlever' the levered or equity beta (Hamada, 1972). The Hamada equation is given by:

$$\beta_{asset} = \frac{\beta_{equity}}{1 + (1 - tax) * \frac{Debt}{MarketCapitalization + PreferredStock}} \tag{4.2}$$

In which the statutory corporate tax rate is used for the tax rate in this formula, as the effective tax rate of the companies were often above 100%. Because there is no publicly available comprehensive database that includes statutory corporate tax rate for the sample period examined in this research, data on the corporate taxes were obtained from multiple sources. Corporate tax data on EU countries were obtained from the EC (2020) website, data on corporate tax for countries outside the EU were obtained from KPMG (2002, 2020) and tax data on Saudi Arabia for 2002 was obtained from Trading Economics (2020), this last one after being hand checked on the 2003 to 2018 data to ensure it is the same rates as KPMG. This results in the unlevered or asset beta being used as dependent variable in hypothesis 1.

For hypothesis 2 we examine the cost of debt, measured as the ratio of interest expense from debt over total debt (Eliwa et al., 2019). Hypothesis 3 focuses on financial leverage and is measured by the ratio of total debt divided by total debt plus market capitalization plus liquidation value of preferent shares, as is done in congruence with Gao and Connors (2011).

4.1.2 Independent Variables

The independent variable used to examine the hypotheses is the yearly volume of renewable energy generated by companies, measured in gigajoules. This variable has only been used in the study of Ruggiero and Lehkonen (2017) and allows us to research the effect of renewable energy generation directly instead of indirectly via proxies. Because the volume of green energy produced by companies can vary greatly, we transformed the amount generated into its natural logarithm to be able to better compare the output throughout the sample (Ruggiero and Lehkonen, 2017). The future value of renewable energy generation is taken when testing hypothesis 3, and hypothesis 3 in combination with hypotheses 4, 5 and 6 to determine whether renewable initiatives are often financed with leverage.

4.1.3 Control Variables

Leverage is included as a control variable for the cost of debt as taking on a higher level of leverage increases a company's cost of debt as the chance on default increases (Sharfman and Fernando, 2008; Waddock and Graves, 1997). Leverage is measured as total debt over total debt plus market capitalization plus the value of the preferred shares (Gao and Connors, 2011). The book value of total debt is taken instead of the market value, as the latter is hard to measure as it is typically not observable (Adam and Goyal, 2008).

Firm size may also be of influence as larger firms are more subjected to analyst scrutiny, through which the company's cost of equity and cost of debt are more sensitive to news and changes in operations (Sharfman and Fernando, 2008) and economies of scale may be of relevance in renewable projects (Agarwal and Berens, 2009). Moreover, larger companies fail less often so size may be a proxy for probability of default and should have a positive effect on cost of debt (Gao and Connors, 2011). Firm size is measured as the natural log of book value of total assets, as is custom in relevant literature (Agarwal and Berens, 2009; El Ghoul et al., 2018; Gonenc and Scholtens, 2017; Gupta, 2018).

Interest coverage ratio is expected to have an influence on cost of debt and financial leverage as it indicates how well a company can handle its interest payments. A high interest coverage ratio therefore suggests a company can handle acquiring additional leverage and the accompanying interest charges, meaning it is likely that firms with a higher ratio have a lower cost of debt (Eliwa et al., 2019). The interest coverage ratio is defined as operating income over interest expense (Eliwa et al., 2019). The interest coverage ratio is lagged by one year for the cost of debt and leverage models to avoid reversed causality in which the interest coverage ratio is caused by the cost of debt or leverage.

The market-to-book ratio indicates whether a firm's market value is higher than its book value. If a firm is overvalued, the firm has a high market-to-book ratio and is expected to issue stock instead of debt when in need for financing. This could result in a negative relation between the market-to-book ratio and financial leverage (Gao and Connors, 2011). The market-to-book ratio is measured as a company's market capitalization divided by its book value of equity (Chava, 2014; Gao and Connors, 2011; Gupta, 2018).

4.2 Models

In examining the effect of environmental initiatives such as renewable projects on financial performance, there are three main approaches identified in literature: portfolio analyses, event studies and long-term studies using regression analysis (Ambec and Lanoie, 2008). Of these, portfolio analysis is heavily dependable on the skills of management and event studies can only discern effects up to a few days after the announcement to avoid interference of confounding events. This results in long-term regression analysis studies being the most reliable method, especially since control variables can be added to isolate and verify the effect of the explanatory on the dependent variable. In the regression analyses panel data is used, as it incorporates information about a large number of companies through multiple years. The advantage this contains over cross-sectional or time series data is that panel data allows for more efficient econometric estimates and better controls for omitted variables (Hsiao, 2003). To examine the hypotheses and answer the research question, linear regression analyses are performed to determine whether renewable energy generation increases, decreased or has no effect on the cost of capital.

4.2.1 Choice of regression analysis

There are three main alternatives in choosing the estimation models when analyzing panel data. These are the pooled regression model, the fixed effect model and the random effect model. The pooled regression model treats all individual-year observations as independent observations, measuring only between-observations and not within-observations (Mertens et al., 2017). This results in the model ignoring the fact that observations are nested within individuals and is not suited for observing the same sample along multiple years, as is the case in this research. The random-effect model exploits both the within and between company variation and estimates the individual's effect randomly by assuming that the intercept consists of a common average value for all individuals plus an error term that captures the individual differences as a random deviation from the average. The fixed-effects model measures variance within companies, from year to year, and not between companies. This is the preferred model in this research because only the variation within companies show the impact of generating more renewable energy. Fixed-effect models also control for time-invariant variables that are not included in the model and differ between individuals (Gujarati, 2009). This results in fixed-effect models also accounting for possible endogeneity issues by controlling for time-invariant omitted variables.

Fixed-effect models have two common estimation methods, this being the least squares dummy variable (LSDV) and the within-effect method (Gujarati, 2009). In the LSDV method, the separate intercepts are introduced through dummy variables for each individual except the first one. The disadvantage of adding these dummy variables is that these consume degrees of freedom and result in less efficient estimations. This is especially true when examining a dataset with a large number of individuals, such as the dataset in this research. Besides this, the addition of all those dummy variables sharply increases the possibility of multicollinearity. The within-effect method eliminates heterogeneity between individuals by differencing sample observations around their sample means, instead of using dummy variables as in the previous method. By doing so, this method expresses the values of the dependent and explanatory variables for each individual as deviations from the sample mean. The disadvantages of within-effects are that the variances of the coefficients are larger and that differencing a variable can remove long term effects (Gujarati, 2009). Because the dataset used in this research contains 163 individuals, or firms, the within-effect method is more efficient.

4.2.2 The Models

To isolate the effect of green energy, control variables are added that are expected to influence the dependent variables. Furthermore, a different dependent or independent variable is added to the regression in each model depending on the hypothesis being examined. Hypothesis 1 examines the impact of renewable energy generation on the unlevered equity beta. The regression equation for Model 1 is as follows:

Model 1:

$$Beta = \beta 0 + \beta_1 ReGen + \beta_2 FirmSize + error$$

Hypothesis 2 focuses on the cost of debt financing and the influence of renewable energy generation thereon. This results in the next model being:

<u>Model 2:</u>

$$CoD = \beta_0 + \beta_1 ReGen + \beta_2 IntCov_{t-1} + \beta_3 Leverage + \beta_4 FirmSize + error$$

Hypothesis 3 examines correlation between renewable generation and leverage:

<u>Model 3:</u>

$$Leverage = \beta_0 + \beta_1 ReGen_{t+1} + \beta_2 IntCov_{t-1} + \beta_3 MTB + error$$

The fourth hypothesis analyses whether the effect of renewable energy is more pronounced on companies in the oil & gas industry than on multiline- or electric utility companies. This is determined by adding interaction terms between renewable generation and the categorical variable Industry that has the value of 0 for the electric utility companies, 1 for the oil & gas companies and 2 for multiline utility firms. Note that although the categorical variable Industry is also included in the model without the interaction, this is a time-invariant variable and is thus omitted in the regression because fixed-effects models already account for it. The following models are analyzed for hypothesis 4:

<u>Model 4:</u>

$$\begin{aligned} Beta = {} & \beta_0 + \beta_1 ReGen + \beta_2 ReGen * IndOilGas + \beta_3 ReGen * IndMultUt \\ & + \beta_4 OilGas + \beta_5 MultUt + \beta_6 FirmSize + error \end{aligned}$$

<u>Model 5:</u>

$$\begin{aligned} CoD = {} & \beta_0 + \beta_1 ReGen + \beta_2 ReGen * OilGas + \beta_3 ReGen * MultUt + \beta_4 OilGas \\ & + \beta_5 MultUt + \beta_6 IntCov_{t-1} + \beta_7 Leverage + \beta_8 FirmSize + error \end{aligned}$$

Model 6:

$$Leverage = \beta_0 + \beta_1 ReGen_{t+1} * OilGas + \beta_2 ReGen_{t+1} * MulUt + \beta_3 ReGen_{t+1} * ElecUt + \beta_4 IntCov_{t-1} + \beta_5 MTB + error$$

The fifth hypothesis examines whether the effect of renewable generation is more pronounced in recent years. To determine this, a dummy variable is used that has the value 0 for the period of 2002-2010 and 1 for the period of 2011-2018. After, interaction terms are made between renewable generation and the period dummy. This results in the following models:

Model 7:

$$Beta = \beta_0 + \beta_1 ReGen + \beta_2 ReGen * Period + \beta_3 Period + ß4 FirmSize + error$$

Model 8:

$$CoD = \beta_0 + \beta_1 ReGen + \beta_2 ReGen * Period + \beta_3 Period + \beta_4 IntCov_{t-1} + \beta_5 Leverage + \beta_6 FirmSize + error$$

Model 9:

$$Leverage = \beta_0 + \beta_1 ReGen_{t+1} + \beta_2 ReGen_{t+1} * Period + \beta_3 Period + \beta_4 IntCov_{t-1} + \beta_5 MTB + error$$

The sixth and last hypothesis focuses on whether the impact of renewable energy is more pronounced on European companies. This is examined through the use of an interaction term between renewable energy and a dummy variable that takes the value 1 for firms based in Europe. Note that the European dummy without the interaction term is added to the model but is omitted in the regression due to being a time-invariant variable.

Model 10:

$$Beta = ß0 + ß1 ReGen + ß2 ReGen * EU + ß3 EU + ß4 FirmSize + error$$

Model 11:

$$CoD = ß0 + ß1ReGen + ß2ReGen * EU + ß3EU + ß4IntCov_{t-1} + ß5Leverage + ß6FirmSize + error$$

<u>Model 12:</u>

$$Leverage = ß0 + ß1ReGen_{t+1} + ß2ReGen_{t+1} * EU + ß3EU + ß4IntCov_{t-1} + ß5MTB + error$$

5. Data

This chapter focuses on how the dataset is compiled and on the descriptive statistics. First information is provided on the sample selection procedure. After, statistics are presented on the geographical distribution and temporal distribution, which are discussed together with the summary statistics. Lastly, the correlation matrix is presented to examine possible cases of multicollinearity.

5.1 Sample selection

The Thomson Reuters DataStream database was used to compile a dataset of public electric utility, multiline utility and oil & gas companies that produce renewable energy. To obtain this dataset, first a search was conducted with the equity screener for all public companies in the electricity and oil & gas industry, which resulted in 11,081 securities. A screening followed on major securities and primary listings to narrow this dataset down to only one security per company and 4,750 companies remained in the sample. In this sample the variable Renewable Energy Produced was added to see how many firms had data available and the sample reduced to 173 companies. After removing duplicate firms and firms with only 0 or missing values on renewable energy generation, 170 companies were left.

Financial data was gathered for these companies and 7 were removed for not having sufficient financial information, resulting in an unbalanced dataset containing 163 firms. Subsequently, 23 firms were removed from the sample that had no subsequent datapoints on renewable energy. Those firms were removed because the impact of generating more renewable energy on the dependent variables cannot be determined if firms don't have data on subsequent years. The earliest date that Thomson Reuters started recording data on renewable energy production is 2002, therefore the dataset contains data on the years 2002-2018 to include as much observations as possible. The final sample therefore consists of data on 140 firms between the years 2002 and 2018, which results in 2,380 firm years being examined. The sample construction is summarized in Table 5.1.

Table 5.1: Sample selection

The sample selection presents an overview of the steps taken to obtain data on the final 140 firms in the sample. The data was downloaded from the Thomson Reuters Eikon DataStream database.

Selection criteria	Firms removed	Firms remaining
Sector electricity and oil & gas producers		11.081
Removed non-major securities	1.646	9.435
Removed nonprimary listings	4.685	4.75
Removed if no data on renewable energy	4.512	173
Removed if only zeros as data	2	171
Removed duplicate	1	170
Removed firms without financial information	7	163
Removed if no renewable energy data for subsequent years	23	140

5.2 Descriptive statistics

Table A.1 and A.2 present the geographical distribution of the firms in the sample. Of the total 140 companies in the dataset, 32 companies are European and 34 are from the United States. This dataset includes 21 oil & gas companies, of which 5 are European and 1 is from the US. The dataset shows that both European and US oil & gas firms are relatively underrepresented. The multiline firms are spread more evenly, with 4 out of 10 firms being European and an even 4 being from the US. Lastly, the electric utility sample is the largest by far, comprising of 109 firms of which 23 are European and 29 are from the US. With the higher amount of electric utility firms relative to oil & gas or multiline firms, the results of non-industry specific regressions will be heavily skewed towards electric utility firms.

Table A.3 provides an overview of the temporal distribution of datapoints on the renewable energy variable. Noticeable is that there is only a small number of firms with data on this variable during the first few years. The number of firms with data on this variable steadily increased, with 2010 as threshold in which there are more firms with than without data on renewable energy generation. The steadily increasing number of firms that reported data on their renewable energy production is in line with the theoretical framework described earlier that there is an increased awareness over the years for sustainability. It is also noticeable that while the number of firms in the energy sector producing renewable energy or providing information on their green energy initiatives is generally increasing, there is an exception in 2007 and the years after the 2016. Especially the decline after 2016 seems contradicting with theory, although it could be explained by firms putting their renewable energy business into subsidiaries that belong to the renewable energy industry instead of the oil & gas, electric- or multiline utility industries.

Looking at the summary statistics in Table 5.2 below and Table A.4, the median beta for firms in the energy sector is 0.397 which means that firms in this sector are on average relatively unsensitive to market risks. A standard deviation of 0.322 shows that there are differences in this sensitivity, but the firms are generally robust to market swings. Oil & gas companies have beta's that are double that of the electric- or multiline utilities, which is in line with the theories that the oil & gas industry faces more risk than the other industries. The median cost of debt that companies have to pay as interest is 5.2% in the energy sector, with large deviations of around 9% higher or lower. Firms in the oil & gas industry pay lower interest rates on their debt than the utilities, but their standard deviation indicate that there are larger differences between oil & gas firms. The cost of debt could very well be related to the relative amount of leverage of the industries. This higher cost of debt is the additional compensation creditors require for the greater risk on default. As stated earlier, companies in the power sector primarily finance their projects with debt. This is seen in the electric- and multiline utilities, with a median debt level close to 50%, while oil & gas companies have a substantial lower debt level of only 18%. Looking at the amount of renewable energy generated, electric utility companies generate the highest amount and oil & gas companies the lowest. This is expected, as renewable resources generate electricity and is therefore closer to the electric utility business than oil & gas. It is noticeable that oil & gas firms have substantially higher standard deviations from their green energy generating median, meaning that some oil & gas firms do commit more to these initiatives than others. European firms generate more green energy on average than other firms, which provides evidence for the notion that the more stringent commitment to renewables that Europe has results in a more favorable environment for renewable developments.

For the control variables, the size of oil & gas companies is larger on average than utility companies, although there are larger differences between them as well. The interest coverage ratio of oil & gas firms is substantially higher than that of the utilities. The higher interest coverage ratio is expected as both the average debt level and cost of debt of the utilities being higher. What is surprising is the large difference in interest coverage ratio between the mean and median of oil & gas companies together with a very large standard deviation, indicating that there are some extreme outliers present in the sample. This is due to some companies having a very low leverage ratio and interest expense, which inflates its coverage ratio. The median market-to-book ratios of firms in all industries are between 1.4 and 1.5, which indicates that the firms are in general overvalued. Oil & gas companies have on average a slightly lower market-to-book ratio than the utility companies.

5.3 Correlation matrix

Table A.5 presents the Pearson correlation matrix which shows that correlation coefficients and significance levels for the dependent, independent and control variables. The correlation matrix is also used to test the multicollinearity between variables. All correlations are below 0.5, indicating that multicollinearity is not an issue in this dataset. The highest and significant correlation is between the beta and leverage with a correlation of 0.440, significant at the 1% level. The relatively high correlation between the beta and leverage is unexpected, since the beta is unlevered and the capital structure, including leverage, is thereby taken out of the beta.

Table 5.2: Summary statistics

Summary statistics for the dependent, independent and control variables. The sample is comprised of all firm in the energy sector that have data on their renewable energy production in the Thomson Reuters Eikon DataStream database. The unlevered beta is the 5-year monthly equity beta unlevered using the Hamada equation, the cost of debt is the ratio of the interest expense from debt over the total debt, leverage is the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares, renewable generation is the natural logarithm of the amount of renewable energy produced in gigajoules, firm size is the natural logarithm of total assets, the lagged interest coverage ratio is the operating income over interest expense and is lagged one year to avoid reverse causality, market-to-book ratio is the firm's market capitalization divided by its book value of equity, industry is a categorical variable that has the value 0 for the electric utility industry, 1 for the oil & gas industry and 2 for the multiline utility industry, the period dummy has the value 1 for the period of 2011-2018, and the European dummy has the value 1 for firm's that have their headquarters in Europe. The table shows the means, medians and standard deviations (SD) for the variables in the sample, as well as for the subsample of European firms.

	All firms			European firms		
	Mean	Median	SD	Mean	Median	SD
Beta	0.443	0.397	(0.322)	0.461	0.474	(0.289)
Cost of debt	0.058	0.052	(0.091)	0.055	0.044	(0.150)
Leverage	0.421	0.416	(0.202)	0.393	0.389	(0.192)
Renewable generation	16,200	16,666	(2,622)	16,700	17,082	(2,613)
Firm size	16,347	16,412	(1,454)	16,848	16,679	(1,272)
Interest coverage ratio	37,691	3,088	(1,138,203)	8,857	3,988	(14,541)
Market-to-book ratio	1,619	1,450	(1,390)	1,688	1,400	(1,091)
Industry	0.293	0.000	(0.592)	0.406	0.000	(0.702)
Period dummy	0.471	0.000	(0.499)	0.471	0.000	(0.500)
European dummy	0.229	0.000	(0.420)	1,000	1,000	(0.000)

6. Results

This chapter focuses on the results of the analyses in which the methodology is used to answer the hypotheses and the research question. Fixed-effects models are used to analyze the panel data, as mentioned in the methodology. The chapter is divided into results regarding the beta, cost of debt and the percentual amount of financial leverage. Hypotheses 4, 5 and 6 try to discern the effects of producing renewable energy over industries, time periods and regions and are discussed together with their respective dependent variables. A modified Wald test is performed to test groupwise heteroskedasticity. Because heteroskedasticity is present in all models, robust standard errors are used that also controls for autocorrelation.

6.1 Influence on the unlevered beta

Table 6.1 presents the results of the fixed-effect models to determine the influence of renewable energy generation on the unlevered beta. The models are first regressed without the control variable firm size and after with the control variable included. In Model 1, testing hypothesis 1, the beta is first regressed on the renewable energy production variable only. The renewable energy variable is statistically significant at the 5% level and has a negative coefficient (-0.018). When firm size is added however, the renewable energy variable is statistically insignificant with a high p-value. The adjusted within R2 level increased to 4%, indicating that including Firm size lead to the model better explaining the within unit variation of the unlevered beta. The variable Firm size is significant at the 5% level and has a negative coefficient, meaning that firm size does on average decrease the unlevered beta. The change in the renewable energy variable by the inclusion of Firm size indicates that a large part of what renewable energy seemed to explain was due to firm size and that renewable energy generation does not seem to have a significant effect on the unlevered beta. This is contrary to expectations and the null hypothesis of hypothesis 1 therefore cannot be rejected.

Model 4 tests the beta for hypothesis 4 that the effects of renewable energy are more pronounced in the oil & gas industry than in the electric or multiline utility industries. First the beta is regressed only on the renewable energy variable, the industry variable and the interaction between those two. The only significant variable here is the interaction term with the electric utility industry at the 5% level. Including Firm size in the model results in only Firm size being significant at the 5% level, as was the case in Model 1. The results of this model are also contrary to expectations and the null hypothesis of hypothesis 4 regarding the beta also cannot be rejected.

Model 7 analyses hypothesis 5 whether the effects of renewable generation are stronger in more recent years than in those of the past. Renewable energy generation is significant at the

5% level for the period between 2002 and 2010 when Firm size is not included in the model. When firm size is included, only Firm size is significant at the 10% level. This indicates that again part of the variation that renewable energy seemed to explain was due to firm size. The results indicate that the null hypothesis can't be rejected when concerning the unlevered beta.

The last model that includes the beta as dependent variable is Model 10 testing hypothesis 6. In this model, an interaction term between green energy production and a dummy for companies headquartering in Europe is analyzed. The renewable energy variable is significant with the Europe dummy being 0 and without the inclusion of firm size. Including firm size results again in only firm size being significant, at the 5% level. This indicates again that the variance renewable energy seemed to explain is due to firm size and that generating renewable energy does not seem to influence the unlevered beta. The null hypothesis of hypothesis 6 cannot be rejected regarding the unlevered beta.

Table 6.1: Regression results - Beta

Regression results for the fixed-effects models, in which all models are regressed with and without control variables. The dependent variable is the 5-year monthly beta unlevered using the Hamada equation. The independent variable in Model 1 is renewable generation measured as the natural logarithm of the amount of renewable energy produced in gigajoules. The independent variable in Model 4 is an interaction between renewable generation and an industry variable that has the value 0 for the electric utility industry, 1 for the oil & gas industry and 2 for the multiline utility industry. The independent variable in Model 7 is an interaction between renewable generation and a period dummy has the value 1 for the period of 2011-2018. The independent variable in Model 10 is an interaction between renewable generation and a European dummy that has value 1 for firms that have their headquarters in Europe. The control variables are: a period dummy that has value 1 for 2011-2018, and firm size measured as the natural logarithm of total assets. All models control for heteroscedasticity and autocorrelation by using robust standard errors. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

	Dependent variable: Unlevered beta							
	Model 1		*Model 4*		*Model 7*		*Model 10*	
ReGen	0.018**	-0.007	-0.020**	-0.008	-0.018**	-0.011	-0.018**	-0.007
	(0.045)	(0.413)	(0.022)	(0.337)	(0.033)	(0.218)	(0.045)	(0.405)
ReGen * Ind. Oil & Gas			0.031	0.027				
			(0.4070)	(0.482)				
ReGen * Ind. Multiline			-0.059	-0.061				
			(0.324)	(0.202)				
ReGen * Period dummy					0.016	0.015		
					(0.110)	(0.130)		
ReGen * Europe dummy							-0.003	-0.001
							(0.924)	(0.988)
Period dummy					-0.306**	-0.280*		
					(0.047)	(0.080)		
Firm size		-0.104**		-0.103**		-0.089*		-0.104**
		(0.035)		(0.031)		(0.072)		(0.034)
Constant	0.705***	2.269***	0.791***	2.336***	0.746***	2.099***	0.709***	2.270***
	(0.000)	(0.005)	(0.000)	(0.003)	(0.000)	(0.009)	(0.000)	(0.005)
Observations	1072	1072	1072	1072	1072	1072	1072	1072
Adj. R-squared	0.009	0.040	0.020	0.051	0.033	0.053	0.009	0.040

6.2 Influence on the cost of debt

Table 6.2 and 6.3 present the results of the cost of debt regressed on the renewable energy production variable and the control variables firm size, leverage and the lagged value of the interest coverage ratio, as is presented in Model 2 testing hypothesis 2. The green energy production variable is significant at the 1% level when the control variables are excluded. When including the control variables leverage and the lagged interest coverage ratio the green energy variable is still significant at the 5% level. When firm size is included however, this changes and the renewable variable is statistically insignificant with a high p-value (0.160). Furthermore, all control variables except for firm size are also statistically insignificant. This provides evidence that part of the variation that the green energy, leverage and interest coverage variables seemingly explained was due to firm size. While this is contrary to the expectations of hypothesis 2 that renewable energy is associated with a reduction in the cost of debt, the effect of including firm size on the renewable variable seems in accordance with the models examining the beta. The effect that firm size has on the other control variables, however, is not expected. The results of model 2 do not provide evidence that the null hypothesis can be rejected.

Hypothesis 4 is tested with Model 5 and includes the industry interaction terms to analyze whether the effects are more pronounced in the oil & gas industry than in the electric or multi-line utility industry. Without the control variables, only the interaction term with the electric utility industry is significant, at the 1% level. The introduction of the control variable interest coverage ratio roughly follows the pattern of Model 2, in which the inclusion the interest coverage ratio does not change the renewable energy variables substantially, the inclusion of leverage still results in a significant renewable energy variable and firm size again results in only firm size being significant (0.031). This indicates that the null hypothesis of hypothesis 4 cannot be rejected and renewable energy does not significantly influence the cost of debt in any of the industries.

Hypothesis 5 regarding the cost of debt is analyzed with Model 8. This model examines whether the effects of renewable energy on the cost of debt are more pronounced in recent period than in the earlier period. Only the interaction with period 1 is significant, at the 5% level, when the control variables are not included in the model. Including the control variables follow the same pattern as with Model 4. No evidence is found in favor of rejecting the null hypothesis.

Model 11 focuses on hypothesis 6 and the interaction terms with the Europe dummy. The interaction with the Europe dummy is insignificant, while the renewable variable excluding the Europe interaction is. The inclusion of the control variables results in accordance with the previous models that leverage and the lagged interest coverage ratio do not change the outcomes noticeably, but that firm size again does result in the other variables being statistically insignificant. This indicates that the null hypothesis of hypothesis 6 regarding the cost of debt cannot be rejected and that producing renewable energy does not seem to influence the cost of debt of firms in the energy sector.

Table 6.2: Regression results – Cost of debt

Regression results for the fixed-effects models, in which all models are regressed with and without control variables. The dependent variable is the cost of debt measured as the ratio of the interest expense from debt over the total debt. The independent variable in Model 2 is renewable generation measured as the natural logarithm of the amount of renewable energy produced in gigajoules. The independent variable in Model 5 is an interaction between renewable generation and an industry variable that has the value 0 for the electric utility industry, 1 for the oil & gas industry and 2 for the multiline utility industry. The control variables are: the lagged interest coverage ratio measured as the operating income over interest expense and lagged one year to avoid reverse causality, leverage measured as the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares, and firm size measured as the natural logarithm of total assets. All models control for heteroscedasticity and autocorrelation by using robust standard errors. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

	Dependent variable: Cost of debt									
	Model 2					*Model 5*				
ReGen	0.002***	0.002***	-0.002**	-0.001	-0.001	-0.002***	-0.002***	-0.001*	-0.001	-0.001
	(0.006)	(0.007)	(0.014)	(0.129)	(0.160)	(0.002)	(0.002)	(0.095)	(0.268)	(0.441)
ReGen * Ind. Oil & Gas						-0.002	-0.003	-0.001	-0.002	-0.003
						(0.618)	(0.539)	(0.671)	(0.533)	(0.494)
ReGen * Ind. Multiline						-0.001	-0.000	-0.002	-0.001	-0.001
						(0.798)	(0.965)	(0.546)	(0.618)	(0.548)
Interest Coverage Ratio$_{t\text{-}1}$		-0.000*			-0.000		-0.000			-0.000
		(0.099)			(0.105)		(0.121)			(0.109)
Leverage			-0.048**		-0.043			-0.048**		-0.043
			(0.048)		(0.110)			(0.044)		(0.106)
Firm size				-0.011***	-0.007**				-0.011***	-0.007**
				(0.000)	(0.040)				(0.000)	(0.031)
Constant	.0088***	0.088***	0.099***	0.255***	-0.210***	0.084***	0.083***	0.096***	0.252***	0.207***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1084	1071	1075	1084	1062	1084	1071	1075	1084	1062
Adj. R-squared	0.012	0.014	0.080	0.045	0.094	0.014	0.016	0.081	0.047	0.096

Table 6.3: Regression results – Cost of debt continued

Regression results for the fixed-effects models, in which all models are regressed with and without control variables. The dependent variable is the cost of debt measured as the ratio of the interest expense from debt over the total debt. The independent variable in Model 8 is an interaction between renewable generation and a period dummy has the value 1 for the period of 2011-2018. The independent variable in Model 11 is an interaction between renewable generation and a European dummy that has value 1 for firms that have their headquarters in Europe. The control variables are: a period dummy that has value 1 for 2011-2018, the lagged interest coverage ratio measured as the operating income over interest expense and lagged one year to avoid reverse causality, leverage measured as the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares, and firm size measured as the natural logarithm of total assets. All models control for heteroscedasticity and autocorrelation by using robust standard errors. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

	Dependent variable: Cost of debt									
	Model 8					*Model 11*				
ReGen	-0.002**	-0.002**	-0.001*	-0.001	-0.001	-0.002**	-0.002**	-0.002**	-0.001	-0.001
	(0.048)	(0.048)	(0.061)	(0.235)	(0.203)	(0.018)	(0.018)	(0.032)	(0.161)	(0.179)
ReGen * Period dummy	-0.000	-0.000	0.000	-0.000	0.000					
	(0.916)	(0.886)	(0.564)	(0.893)	(0.632)					
ReGen * Europe dummy						0.000	0.001	0.001	0.001	0.001
						(0.908)	(0.722)	(0.566)	(0.642)	(0.422)
Period dummy	-0.006	-0.005	-0.011	-0.004	-0.009					
	(0.616)	(0.653)	(0.352)	(0.744)	(0.452)					
Interest Coverage Ratio$_{t-1}$		-0.000			-0.000		-0.000*			-0.000
		(0.113)			(0.123)		(0.098)			(0.101)
Leverage			-0.043		-0.041			-0.049**		-0.043
			(0.118)		(0.166)			(0.049)		(0.110)
Firm size				-0.009***	-0.006*				-0.011***	-0.007**
				(0.002)	(0.077)				(0.000)	(0.040)
Constant	0.079***	0.080***	0.096***	0.210***	0.190***	0.088***	0.088***	0.098***	0.254***	0.208***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1084	1071	1075	1084	1062	1084	1071	1075	1084	1062
Adj. R-squared	0.042	0.042	0.089	0.059	0.098	0.012	0.014	0.080	0.045	0.095

6.3 Influence on financial leverage

Table 6.4 and 6.5 present the result of the fixed-effects models in which the percentual amount of financial leverage is regressed on the forward renewable energy generation and the control variables interest coverage and the market-to-book ratio. The first model to analyses the overall effect of renewable generation according to hypothesis 3 is Model 3. First leverage is regressed on the renewable production variable only and the variable is significant (0.031) with a positive coefficient. Including the lagged interest coverage ratio doesn't change the significance coefficient substantially. The lagged interest coverage variable itself is statistically significant, but economically insignificant due to the small coefficient (-0.000). After adding the market-to-book ratio to the model, green energy generation is still economically and statistically significant at the 10% level with a positive coefficient, indicating that the forward renewable energy production is on average associated with an increase in leverage. The interest coverage ratio is still statistically significant, although at the 10% level, but also still economically insignificant. The market-to-book ratio is statistically insignificant. The statistical and positive economical significance of the renewable generation variable in Model 3 provides evidence that the null hypothesis can be rejected and that the future renewable energy production is associated with an increase in leverage.

Model 6 analyses hypothesis 4 and the impact of the industry interaction term on financial leverage. Leverage is first regressed on the interactions of the renewable variable with the industry dummies. The only significant interaction is that with the electric utility industry, at the 10% level, with a positive coefficient. This does not seem to support the hypothesis that the oil & gas industry has the most pronounced effect. Adding the lagged interest coverage ratio does not change the renewable generation variable and its interactions meaningfully. The lagged interest coverage ratio is statistically significant at the 5% level but is again economically not. Including the market-to-book ratio decreases the significance of the electric utility interaction, although it remains significant at the 10% level (0.093) with a positive coefficient. The control variables follow the same pattern as with the previous model. Although this model found that producing renewable energy is associated with an increase in leverage for electric utility firms, there is no evidence for rejecting the null hypothesis.

Model 9 examines hypothesis 5 in which the effect in different time periods are compared. Without the control variables included in the model both the interactions are economically and statistically insignificant and including the control variables does not change this. Only the lagged interest coverage ratio is significant statistically, but not economically, as was expected from the previous models. Model 9 does not support rejecting the null hypothesis.

Model 12 analyses the impact of the Europe interaction term on financial leverage. The variables follow the same pattern as the previous model, in which the independent variables and interaction is not significant with or without the control variables. The lagged interest coverage ratio and market-to-book ratio also follow the same pattern. Model 12 does also not provide evidence of rejecting the null hypothesis.

Table 6.4: Regression results - Leverage

Regression results for the fixed-effects models, in which all models are regressed with and without control variables. The dependent variable is leverage measured as the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares. The independent variable in Model 3 is renewable generation measured as the natural logarithm of the amount of renewable energy produced in gigajoules. The independent variable in Model 6 is an interaction between renewable generation and an industry variable that has the value 0 for the electric utility industry, 1 for the oil & gas industry and 2 for the multiline utility industry. The control variables are: the lagged interest coverage ratio measured as the operating income over interest expense and lagged one year to avoid reverse causality, and the market-to-book ratio measured as the firm's market capitalization divided by its book value of equity. All models control for heteroscedasticity and autocorrelation by using robust standard errors. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

	Dependent variable: Leverage							
	Model 3				*Model 6*			
ReGen	0.014**	0.014**	0.011*	0.010*	0.014**	0.014**	0.011*	0.011*
	(0.019)	(0.025)	(0.077)	(0.092)	(0.046)	(0.046)	(0.095)	(0.093)
ReGen * Ind. Oil & Gas					0.010	0.009	0.003	0.002
					(0.567)	(0.613)	(0.831)	(0.894)
ReGen * Ind. Multiline					-0.021	-0.026*	-0.018	-0.023*
					(0.126)	(0.069)	(0.157)	(0.089)
Interest Coverage Ratio$_{t-1}$		-0.000		-0.000		-0.000		-0.000
		(0.178)		(0.157)		(0.186)		(0.160)
Market-to-book ratio			-0.020	-0.020			-0.02	-0.020
			(0.278)	(0.280)			(0.279)	(0.282)
Constant	0.229**	0.241**	0.315***	0.325***	0.258***	0.270***	0.329***	0.338***
	(0.020)	(0.014)	(0.008)	(0.006)	(0.008)	(0.006)	(0.005)	(0.004)
Observations	1079	1066	1077	1065	1079	1066	1077	1065
Adj. R-squared	0.016	0.018	0.065	0.068	0.019	0.023	0.067	0.071

Table 6.5: Regression results – Leverage continued

Regression results for the fixed-effects models, in which all models are regressed with and without control variables. The dependent variable is leverage measured as the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares. The independent variable in Model 9 is an interaction between renewable generation and a period dummy has the value 1 for the period of 2011-2018. The independent variable in Model 12 is an interaction between renewable generation and a European dummy that has value 1 for firms that have their headquarters in Europe. The control variables are: a period dummy that has value 1 for 2011-2018, the lagged interest coverage ratio measured as the operating income over interest expense and lagged one year to avoid reverse causality, and the market-to-book ratio measured as the firm's market capitalization divided by its book value of equity. All models control for heteroscedasticity and autocorrelation by using robust standard errors. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

	Dependent variable: Leverage							
	Model 9				*Model 12*			
ReGen	0.002	0.002	0.001	-0.000	0.109	0.011	0.008	0.008
	(0.743)	(0.811)	(0.930)	(0.996)	(0.105)	(0.115)	(0.218)	(0.228)
ReGen * Period dummy	0.011**	0.0115**	0.010*	0.010*				
	(0.059)	(0.054)	(0.078)	(0.071)				
ReGen * Europe dummy					0.017	0.015	0.015	0.014
					(0.324)	(0.367)	(0.346)	(0.394)
Period dummy	-0.115	-0.118	-0.102	-0.105				
	(0.248)	(0.236)	(0.282)	(0.267)				
Interest Coverage Ratio$_{t-1}$		-0.000		-0.000		-0.000		-0.000
		(0.176)		(0.159)		(0.177)		(0.157)
Market-to-book ratio			-0.016	0.015			-0.020	-0.020
			(0.327)	(0.331)			(0.279)	(0.281)
Constant	0.374***	0.384***	0.430***	0.439***	0.207*	0.221**	0.295**	0.306**
	(0.001)	(0.001)	(0.000)	(0.000)	(0.052)	(0.038)	(0.020)	(0.015)
Observations	1079	1066	1077	1065	1079	1066	1077	1065
Adj. R-squared	0.128	0.132	0.160	0.165	0.019	0.021	0.068	0.070

6.4 Robustness tests

When examining the effects on the unlevered beta and the cost of debt, firm size had a significant effect in which all other variables seemed to not be able to explain any within unit variance of the dependent variables. This effect is unexpected and warrants further research. The further research is twofold. First the effects of generating renewable energy on the unlevered beta and cost of debt is analyzed for small, medium and large sized firms by separating the sample into three quantiles based on firm size. The second research is performed by analyzing the effects based on quantiles of renewable generation in comparison to the size of the firm. The latter examines whether the effects are different for firms that produce a lot of renewable energy in comparison with their firm size than for firm that produce only a small amount of renewable energy compared to their firm size. Renewable energy is divided by firm size to gain an insight in whether the amount of energy produced is negligible or substantial for the firms because the total energy production is unknown. The corresponding models for the small, medium and large firm sizes are:

<u>Model 13:</u>

$$\begin{aligned} Beta = \beta_0 &+ \beta_1 ReGen + \beta_2 ReGen * FirmSizeQ2 + \beta_3 ReGen * FirmSizeQ3 \\ &+ \beta_4 FirmSizeQ2 + \beta_5 FirmSizeQ3 + \beta_6 FirmSize + error \end{aligned}$$

<u>Model 14:</u>

$$\begin{aligned} CoD = \beta_0 &+ \beta_1 ReGen + \beta_2 ReGen * FirmSizeQ2 + \beta_3 ReGen * FirmSizeQ3 \\ &+ \beta_4 FirmSizeQ2 + \beta_5 FirmSizeQ3 + \beta_6 IntCov_{t-1} + \beta_7 Leverage \\ &+ \beta_8 FirmSize + error \end{aligned}$$

The models for the regressions based on quantiles of renewable generation over firm size are:

<u>Model 15:</u>

$$\begin{aligned} Beta = \beta_0 &+ \beta_1 ReGen + \beta_2 ReGen * \frac{ReGen}{FirmSizeQ2} + \beta_3 ReGen * \frac{ReGen}{FirmSizeQ3} \\ &+ \beta_4 \frac{ReGen}{FirmSizeQ2} + \beta_5 \frac{ReGen}{FirmSizeQ3} + \beta_6 FirmSize + error \end{aligned}$$

<u>Model 16:</u>

$$
\begin{aligned}
CoD = \beta_0 + \beta_1 ReGen + \beta_2 ReGen * \frac{ReGen}{FirmSizeQ2} + \beta_3 ReGen * \frac{ReGen}{FirmSizeQ3} \\
+ \beta_4 \frac{ReGen}{FirmSizeQ2} + \beta_5 \frac{ReGen}{FirmSizeQ3} + \beta_6 IntCov_{t-1} + \beta_7 Leverage \\
+ \beta_8 FirmSize + error
\end{aligned}
$$

Table B.1 presents the results of Models 13 and 14. Model 13 examines whether the effects of producing renewable energy on the unlevered beta are different for small, medium or large firms. The beta is first regressed on the renewable variable, the quantiles and their interaction terms. The only significant variable, at the 10% level, is the interaction between renewable energy and the quantile for medium size firms. Including firm size changes the beforementioned significance to the 5% level (0.035), the variable for the medium size firm quantile to be significant at the 5% level and the variable firm size itself to also be significant at the 5% level. The coefficient of the significant renewable energy variable is positive, indicates that producing renewable energy does actually decrease the unlevered beta on average for medium size firms and does not seem to have a clear relation with small or large firms.

Model 14 examines whether the effects of producing renewable energy on the cost of debt are different for small, medium or large firms. Without the control variables included none of the variables are significant. Including the lagged interest coverage ratio does not cause a change in significance and is not significant itself either. Including leverage only causes leverage itself to be significant at the 10% level and including firm size causes only the constant term to be significant at the 1% level. This indicates that when examining the cost of debt based on quantiles of firm size, no variables in the model explains the within unit variation of the cost of debt.

Table B.2 presents the results of Models 15 and 16. Model 15 examines whether the effects of producing renewable energy on the unlevered beta are different for firms that produce a small medium or high amount of renewable energy compared to their firm size. The beta is first regressed on the renewable variable, the quantiles and their interaction terms. Renewable energy production is significant at the 5% level for the lowest quantile, with a negative coefficient. When firm size is included the dummy variable for the second quantile and the interaction term between renewable generation and the second quantile are significant at the 5% level. Furthermore, the dummy variable has a negative coefficient and the interaction term has positive values, indicating that firms that generate a medium amount of renewable energy compared to their firm size do on average have lower beta's, but that this is not due to the production of renewable energy. Generating renewable energy for these firms seems to increase the unlevered beta and thus systematic risk rather than decrease it.

Model 16 examines whether the effects of producing renewable energy on the cost of debt are different for firms that produce a small medium or high amount of renewable energy compared to their firm size. When the control variables are excluded, producing renewable energy is significant at the 5% level and has a negative coefficient. When the lagged interest coverage ratio is included this relation persists and the lagged interest coverage ratio is also statistically but not economically significant. Including leverage does not change the variables but leverage itself is also significant both statistically and economically. The inclusion of leverage results the categorical variable for the second and third quantile to be significant at the 10% level. Their coefficients are negative, which indicates that firms that produce a medium and high amount of renewable energy compared to their firm size do on average experience a decreased cost of debt, but that that is not because of renewable energy. The interaction term between renewable energy and the second and third quantiles are also significant at the 10% level. Their coefficients are positive, indicating that producing renewable energy on average actually increases cost of debt of firms that produce a medium or high amount of green energy compared to their firm size. The lagged interest coverage ratio is statistically significant but not economically with a small coefficient (-0.000). Firm size is also significant at the 5% level and negative, indicating that larger firms have a lower cost of debt on average.

7. Conclusion

While global energy demand rises and the reserves of polluting fossil fuels are slowly depleting, the need for a transition to cleaner and renewable energy resources becomes pressing. Although this necessity of a clean energy transition is apparent, companies in the energy sector are still slow in adopting renewable initiatives. Governments act and try to incentivize investments in renewable energy by the private sector but are often ill-informed about one of the most important decision inputs: the cost of capital (Donovan and Corbishley, 2016) Estimating the cost of capital is difficult and leads to opposing views in regard to the difference in cost of capital. On one hand Donovan (2015) argues that fossil fuel projects are associated with a higher inherent risk profile, causing renewables to have a lower cost of capital. Other studies, including that of De Jager et al. (2008), indicate that the discount rate of renewables is not necessarily lower than that of their fossil counterparts. The authors argue that renewables have various risks that all have substantial effects on the risk adjusted discount rate (De Jager et al., 2008). This study attempts to add to the growing body of literature on environmental performance by investigating the change in the cost of capital when firms produce more renewable energy. The effect of renewable energy production is analyzed in multiple scenarios to help inform firms on the change in the cost of capital and to attempt to answer the following research question:

What is the effect of generating more renewable energy on the cost of capital of companies within the energy sector?

To examine the effect of generating more renewable energy on the cost of capital, a panel dataset was compiled consisting of 140 public firms active in the energy sector globally that produced renewable energy. To analyze the influence of producing more renewable energy, the cost of capital is split into three parts that were examined separately by the use of regression analysis on linear fixed-effects models. The first hypothesis focused on the unlevered beta and based on studies from various authors including El Ghoul et al. (2018); Feldman et al. (1996); Gupta (2018) it was expected that firms with better environmental performance were associated with reduced equity betas. The results, however, showed no significant effect of generating renewable energy when the control variable firm size was included in the models. The first null hypothesis: *More renewable energy generation is not associated with a reduction in the non-leveraged equity beta of companies in the energy sector*, could therefore not be rejected. Bauer and Hann (2010); Eliwa et al. (2019) stated that a firm's environmental and sustainability efforts were rewarded by the market with a reduced cost of debt. The second null hypothesis stating: *More renewable energy generation is not associated with a reduction in the cost of debt of companies in the energy sector*, attempted to determine if this effect was also apparent when producing renewable energy. However, after running the regressions no significant relation was found. The null hypothesis of hypothesis 2 could also not be rejected. According to Bassen et al. (2006), companies in the energy sector favor debt as financing instrument. Following this statement, the third hypothesis analyzed whether an increase in the relative amount of debt was associated with an increase in renewable energy production in the year after. The results showed evidence that this was the indeed case, and null hypothesis 3: *Renewable energy generation is not associated with an increase in financial leverage of companies in the energy sector*, could therefore be rejected.

After determining the overall effects of renewable energy on the different components of the cost of capital, hypotheses 4, 5 and 6 extended the analysis by examining whether the effects were different across industries, periods and regions. In congruence with Gonenc and Scholtens (2017) arguing that there are substantial differences in the environmental-financial performance relationship along fossil fuel firms in different industries, the difference in effect between the oil & gas, electric utility and multiline utility industry was investigated. The results for the unlevered beta and the cost of debt were insignificant, but an increase in the relative amount of leverage was significantly associated with an increase in the future renewable energy production for companies in the electric utility industry. This however was not as expected and null hypothesis 4: *The impact of generating more renewable energy is not more pronounced on oil & gas than on multiline- or electric utility companies*, could not be rejected. Heinkel et al. (2001) found that the cost of capital of environmentally concerned firms increased with the trend in ethical investing. Chava (2014) reported that with the trend in SRI, creditors likewise progressively started to consider environmental issues in their lending decisions, thereby increasing the interest rates and cost of debt for environmental concerned companies. Following this train of thought, it was examined whether the effects of producing renewable energy were more pronounced in recent years than earlier years. It was found that the unlevered beta was on average lower for firms in earlier years rather than more recent years and this effect was not accountable to the production of green energy. Null hypothesis 5: *The positive effects of renewable energy generations are not more pronounced in recent years*, could again not be rejected. The extent to which companies adopt renewable initiatives is highly dependent on government incentives. Relatedly, Johnstone et al. (2010) found evidence that stringency of environmental policies has a positive impact on environmental patent activity. Building on this, the difference in effects were determined between companies headquartering in and outside of Europe, a region with more stringent policies regarding clean and sustainable energy. No evidence of this was found, however, and null hypothesis 6: *The impact of generating more renewable energy is not most pronounced for companies in Europe*, could again not be rejected.

Two robustness tests were performed in addition to the beforementioned hypotheses. The variable firm size played a substantial role in the models through accounting for a part of the variance that was earlier allocated to the other variables. This resulted in all other variables being insignificant in all models where firm size was included. To examine whether this effect persisted, categorical variables were included that divided the sample in 3 quantiles based on firm size. Evidence was found that producing renewable energy decreases the unlevered beta for medium size companies only. The second robustness test focused on whether the effects were different when firms produced a small, medium or large amount of renewable energy compared to their firm size. Producing renewable energy actually seemed to increase the unlevered beta of firms that generate a medium amount of renewable energy compared to their firm size rather than decrease it. The same increasing effect is also seen with the cost of debt of firms that produce a medium or high amount of green energy compared to their firm size.

The beforementioned results indicate that generating more renewable energy largely have no effect for the cost of equity component of the cost of capital, although evidence has been found that producing renewable energy decreases the beta for medium size companies and increases the beta for firms that generate a medium amount of renewable energy compared to their firm size. Generating more renewable energy also has no impact on the cost of debt component besides an increasing effect for firms that produce a medium or high amount of green energy compared to their firm size. Lastly, evidence has been found that overall, but particularly in the electric utility industry, an increase of leverage is associated with an increased production in the year after. No significant effect from generating renewable energy on the cost of equity and cost of debt has been found. Only the amount of financial leverage is positively associated with an increase in renewable energy production in the year after. The lack of significance can possibly be explained by the empirical research done in this paper being backwards looking and the renewable energy sector still being immature. What this means is that the results do not indicate that the lack of significance will also be the case in the future, when data is analyzed at a moment when the sector is more mature.

7.1 Limitations and recommendations

There a few limitations associated with this study. Most of them originate in the dataset, as the renewable energy sector is relatively immature and data on renewable energy output is still scarce. Amongst others, this is seen in the number of firms the dataset was composed of. This number dropped from the 4.750 major securities of energy companies in the database to only 140 that had data on their renewable energy output for subsequent years. Even with these 140 firms the dataset was heavily unbalanced as many companies had gaps of missing observations between years or did only have data on a few years at all, which made analyzing the effect of renewable energy production less efficient. This can likewise be seen in the temporal distribution of observations in Table A.3. The years before 2010 had more missing than non-missing observations, with the first two years having even less than 20 observations.

As independent variable, this study used the absolute amount of renewable energy produced instead of the relative amount, which would have been preferred as better inferences could have been made. For instance, the impact of generating 10 gigajoule of renewable energy differs for a firm when its total production is 30 gigajoules compared to when the total production is 200 gigajoules. Not using the relative renewable production can have played a substantial role in the lack of significance found in the independent variables. The second robustness test was designed to attempt to address this problem, but while utilizing firm size instead of the total amount of energy produced can give some idea of the relative amount of energy produced is renewable, it is far from ideal.

One of the dependent variables was the beta, which was unlevered via the Hamada formula with the corporate tax rate of the country where the companies' headquarters were. It would have been preferred to use the effective tax rate, but the effective tax rates obtained from the database contained a lot of unrealistic observations that heavily influenced the beta. While the statutory corporate tax rate was not ideal since many firms operated in multiple countries which have different corporate tax rates, the alternative was to exclude the tax rate altogether when unlevering the betas. This alternative was deemed undesirable as it ignored the tax shields that firms obtain when issuing debt.

Except for the lack of relative amount of renewable energy produced, the lack of significance of the independent variables can possibly be caused by potential endogeneity issues that are derived from missing control variables. For example, credit ratings could have been an important determinant of the cost of debt, but these were unavailable for the firms in the dataset.

Moreover, the choice was made in this study to not exclude present outliers in the variables by winsorizing them, because extreme values can convey important information about the companies and the effect of explanatory variables. The downside is that the outliers present in the dataset could have influenced the results.

To obtain a better-balanced dataset with more information on the relative amount of renewable energy produced, it is recommended to repeat this research in a few years when the database has expanded, as a variable concerning the relative amount of renewable energy was present in the database but contained only missing values. Alternatively, one could search through annual reports by hand for the total energy produced and compute the relative amount of renewable energy from there. A suggestion for further research is also to examine companies that made a full transition from fossil fuels to renewable energy and compare the change in their cost of capital. When a few companies, for example the Danish Ørsted, show favorable results, this could help inform oil & gas companies on their transition. Another interesting direction for further research could be to measure the market's reaction when energy firms announce plans for renewable projects in an event study. Furthermore, these studies could be extended to firms outside the energy sector to show that it could be beneficial to think about their sustainability and carbon footprint. Lastly, this study made use of linear regression analyses to examine the effects on the cost of capital. Effects and influences are seldom linear in practice and therefore the suggestion is to repeat this study with machine learning techniques to determine whether the effects are similar when the concept of linearity is abandoned.

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Appendix A: Descriptive statistics

Table A.1: Geographic distribution

The geographical distribution presents an overview of the firms in the dataset and the country they have their headquarters in.

Country	Number of firms	Percentage
Europe	**32**	**22.86%**
Austria	1	0.71%
Belgium	1	0.71%
Czech Republic	1	0.71%
Finland	1	0.71%
France	3	2.14%
Germany	1	0.71%
Greece	1	0.71%
Italy	6	4.29%
Norway	1	0.71%
Poland	5	3.57%
Portugal	2	1.43%
Spain	5	3.57%
United Kingdom	4	2.86%
North America	**47**	**33.57%**
Canada	13	9.29%
United States	34	24.29%
Other	**61**	**43.57%**
Argentina	1	0.71%
Australia	1	0.71%
Bermuda	1	0.71%
Brazil	7	5.00%
Chile	5	3.57%
China	3	2.14%
Colombia	2	1.43%
Hong Kong	4	2.86%
India	8	5.71%
Japan	12	8.57%
Malaysia	2	1.43%
New Zealand	5	3.57%
Philippines	2	1.43%
Russia	5	3.57%
South Africa	1	0.71%
South Korea	1	0.71%
Thailand	1	0.71%
Total	**140**	**100.00%**

Table A.2: Geographic distribution by industry

The geographical distribution presents an overview of the firms in the dataset and the country they have their headquarters in, divided into the 3 industry categories.

	Oil & Gas	Electric utility	Multiline utility
Country		Number of firms	
Europe	**5**	**23**	**4**
Austria	0	1	0
Belgium	0	1	0
Czech Republic	0	1	0
Finland	0	1	0
France	1	1	1
Germany	0	0	1
Greece	0	1	0
Italy	1	4	1
Norway	1	0	0
Poland	1	4	0
Portugal	1	1	0
Spain	0	4	1
United Kingdom	0	4	0
North America	**5**	**37**	**5**
Canada	4	8	1
United States	1	29	4
Other	**11**	**49**	**1**
Argentina	0	1	0
Australia	0	1	0
Bermuda	0	1	0
Brazil	1	6	0
Chile	0	5	0
China	0	3	0
Colombia	0	2	0
Hong Kong	0	4	0
India	3	5	0
Japan	2	10	0
Malaysia	1	1	0
New Zealand	0	4	1
Philippines	0	2	0
Russia	4	1	0
South Africa	0	1	0
South Korea	0	1	0
Thailand	0	1	0
Total	**21**	**109**	**10**

Table A.3: Temporal distribution

The temporal distribution presents an overview of all observations on renewable energy generation in the dataset with the percentage on non-missing observation in the specific year, as well as the distribution for the European firms. Maximum number of observations per year is 140 for all firms and 32 for European firms.

	All firms		European firms	
Year	Observations	Percentage	Observations	Percentage
2002	11	7.86%	5	15.63%
2003	11	7.86%	5	15.63%
2004	20	14.29%	8	25.00%
2005	29	20.71%	12	37.50%
2006	30	21.43%	11	34.38%
2007	26	18.57%	13	40.63%
2008	51	36.43%	14	43.75%
2009	56	40.00%	16	50.00%
2010	76	54.29%	21	65.63%
2011	77	55.00%	20	62.50%
2012	84	60.00%	22	68.75%
2013	91	65.00%	23	71.88%
2014	97	69.29%	23	71.88%
2015	115	82.14%	26	81.25%
2016	122	87.14%	24	75.00%
2017	111	79.29%	24	75.00%
2018	81	57.86%	20	62.50%
Total	**1.088**	**45.71%**	**287**	**52.76%**

Table A.4: Summary statistics by industry

Summary statistics for the dependent, independent and control variables. The sample is comprised of all firm in the energy sector that have data on their renewable energy production in the Thomson Reuters Eikon DataStream database. The unlevered beta is the 5-year monthly equity beta unlevered using the Hamada equation, the cost of debt is the ratio of the interest expense from debt over the total debt, leverage is the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares, renewable generation is the natural logarithm of the amount of renewable energy produced in gigajoules, firm size is the natural logarithm of total assets, the lagged interest coverage ratio is the operating income over interest expense and is lagged one year to avoid reverse causality, market-to-book ratio is the firm's market capitalization divided by its book value of equity, industry is a categorical variable that has the value 0 for the electric utility industry, 1 for the oil & gas industry and 2 for the multiline utility industry, the period dummy has the value 1 for the period of 2011-2018, and the European dummy has the value 1 for firm's that have their headquarters in Europe. The table shows the means, medians and standard deviations (SD) for the variables in the sample divided over the 3 industry categories.

	Oil & Gas industry			Electric utility industry			Multiline utility industry		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Beta	0.734	0.722	(0.338)	0.389	0.353	(0.290)	0.420	0.378	(0.291)
Cost of debt	0.058	0.045	(0.133)	0.058	0.052	(0.085)	0.055	0.052	(0.016)
Leverage	0.201	0.184	(0.149)	0.461	0.448	(0.188)	0.462	0.476	(0.143)
Renewable generation	11,147	11,731	-3,662	16,728	16,882	-1,965	16,016	16,145	-1,642
Firm size	16,772	16,857	-1,938	16,273	16,374	-1,317	16,256	15,937	-1,517
Interest coverage ratio	224,710	14,528	-2,905,088	3,991	2,887	-6,662	2,547	2,564	-1,173
Market-to-book ratio	1,817	1,430	-1,253	1,580	1,440	-1,467	1,633	1,480	(0.647)
Industry	1,000	1,000	(0.000)	0.000	0.000	(0.000)	2,000	2,000	(0.000)
Period dummy	0.471	0.000	(0.500)	0.471	0.000	(0.499)	0.471	0.000	(0.501)
European dummy	0.238	0.000	(0.427)	0.211	0.000	(0.408)	0.400	0.000	(0.491)

Table A.5: Correlation matrix

Pearson's correlation matrix presents the correlations between all variables. The unlevered beta is the 5-year monthly equity beta unlevered using the Hamada equation, the cost of debt is the ratio of the interest expense from debt over the total debt, leverage is the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares, renewable generation is the natural logarithm of the amount of renewable energy produced in gigajoules, firm size is the natural logarithm of total assets, the lagged interest coverage ratio is the operating income over interest expense and is lagged one year to avoid reverse causality, market-to-book ratio is the firm's market capitalization divided by its book value of equity, industry is a categorical variable that has the value 0 for the electric utility industry, 1 for the oil & gas industry and 2 for the multiline utility industry, the period dummy has the value 1 for the period of 2011-2018, and the European dummy has the value 1 for firm's that have their headquarters in Europe. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Beta	1,000									
2. Cost of debt	0.058***	1,000								
	(0.010)									
3. Leverage	0.440***	0.114***	1,000							
	(0.000)	(0.000)								
4. Renewable generation	0.141***	-0.033	0.303***	1,000						
	(0.000)	(0.275)	(0.000)							
5. Firm size	0.066***	0.120***	0.236***	0.223***	1,000					
	(0.003)	(0.000)	(0.000)	(0.000)						
6. Interest coverage ratio$_{t-1}$	0.020	-0.016	0.060***	0.296***	-0.031	1,000				
	(0.385)	(0.465)	(0.008)	(0.000)	(0.167)					
7. Market-to-book ratio	0.053**	0.042*	0.332***	-0.047	0.061***	0.053**	1,000			
	(0.018)	(0.062)	(0.000)	(0.122)	(0.006)	(0.021)				
8. Industry	0.210***	-0.007	0.231***	0.278***	0.059***	0.035	0.037*	1,000		
	(0.000)	(0.737)	(0.000)	(0.000)	(0.006)	(0.120)	(0.091)			
9. Period dummy	-0.023	0.061***	0.148***	-0.014	0.191***	0.021	0.109***	0.000	1,000	
	(0.313)	(0.005)	(0.000)	(0.642)	(0.000)	(0.335)	(0.000)	-1,000		
10. European dummy	0.028	-0.018	0.069***	0.114***	0.177***	-0.013	0.027	0.104***	-0.000	1,000
	(0.219)	(0.402)	(0.002)	(0.000)	(0.000)	(0.554)	(0.228)	(0.000)	-1,000	

Appendix B: Robustness tests

Table B.1: Robustness test 1

Regression results for the fixed-effects models, in which all models are regressed with and without control variables. The dependent variable in Model 13 is the 5-year monthly beta unlevered using the Hamada equation. The dependent variable in Model 14 is the cost of debt measured as the ratio of the interest expense from debt over the total debt. The independent variables are interactions between renewable generation, measured as the natural logarithm of the amount of renewable energy produced in gigajoules, and an interaction between renewable energy and a quantile variable based on firm size that has value 0 for the smallest 33% of firms, 1 for medium sized 33% of firms and 2 for the largest 33% of firms. The control variable in Model 13 are: the quantile variable, and firm size measured as the natural logarithm of total assets. The control variables in Model 14 are: the quantile variable, the lagged interest coverage ratio measured as the operating income over interest expense and lagged one year to avoid reverse causality, leverage measured as the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares, and firm size measured as the natural logarithm of total assets. All models control for heteroscedasticity and autocorrelation by using robust standard errors. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

	Unlevered beta		Cost of debt				
	Model 13		*Model 14*				
ReGen	-0.009	0.004	-0.004	-0.004	-0.003	-0.003	-0.002
	(0.650)	(0.816)	(0.357)	(0.357)	(0.440)	(0.488)	(0.543)
ReGen * Quantile 2	-0.036*	-0.041**	0.001	0.001	0.000	0.001	0.000
	(0.064)	(0.035)	(0.731)	(0.712)	(0.910)	(0.809)	(0.936)
ReGen * Quantile 3	0.010	0.007	0.003	0.003	0.003	0.003	0.002
	(0.611)	(0.730)	(0.494)	(0.507)	(0.518)	(0.520)	(0.566)
Quantile 2 dummy	0.529	0.678**	-0.028	-0.030	-0.011	-0.013	-0.005
	(0.105)	(0.032)	(0.668)	(0.648)	(0.853)	(0.826)	(0.926)
Quantile 3 dummy	-0.298	-0.120	-0.064	-0.062	-0.056	-0.046	-0.043
	(0.386)	(0.719)	(0.357)	(0.367)	(0.380)	(0.470)	(0.492)
Interest Coverage Ratio$_{t-1}$				-0.000			-0.000
				(0.152)			(0.133)
Leverage					-0.047*		-0.044
					(0.061)		(0.106)
Firm size		-0.114**				-0.010***	-0.006
		(0.042)				(0.001)	(0.142)
Constant	0.616**	2.245**	0.123*	0.123*	0.125*	0.268***	0.211***
	(0.049)	(0.018)	(0.079)	(0.079)	(0.068)	(0.002)	(0.002)
Observations	1072	1072	1084	1071	1075	1084	1062
Adj. R-squared	0.035	0.063	0.029	0.029	0.092	0.050	0.099

Table B.2: Robustness test 2

Regression results for the fixed-effects models, in which all models are regressed with and without control variables. The dependent variable in Model 15 is the 5-year monthly beta unlevered using the Hamada equation. The dependent variable in Model 16 is the cost of debt measured as the ratio of the interest expense from debt over the total debt. The independent variables are interactions between renewable generation, measured as the natural logarithm of the amount of renewable energy produced in gigajoules, and an interaction between renewable energy and a quantile variable based on renewable generation over firm size that has value 0 for the least generating 33% of firms, 1 for medium generating 33% of firms and 2 for the most generating 33% of firms when compared to their firm size. The control variable in Model 13 are: the quantile variable, and firm size measured as the natural logarithm of total assets. The control variables in Model 14 are: the quantile variable, the lagged interest coverage ratio measured as the operating income over interest expense and lagged one year to avoid reverse causality, leverage measured as the ratio of total debt divided by total debt plus market capitalization plus the liquidation value of preferred shares, and firm size measured as the natural logarithm of total assets. All models control for heteroscedasticity and autocorrelation by using robust standard errors. The p-values are reported in parentheses. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively.

	Unlevered beta		Cost of debt				
	Model 15		*Model 16*				
ReGen	-0.020**	-0.009	-0.003**	-0.003**	-0.002**	-0.001	-0.001
	(0.033)	(0.370)	(0.020)	(0.017)	(0.029)	(0.186)	(0.176)
ReGen * Quantile 2	0.013	0.045**	-0.001	0.001	0.001	0.002	0.004*
	(0.570)	(0.033)	(0.469)	(0.601)	(0.602)	(0.173)	(0.096)
ReGen * Quantile 3	-0.048	-0.013	-0.001	-0.000	0.001	0.004*	0.004*
	(0.183)	(0.727)	(0.741)	(0.890)	(0.657)	(0.066)	(0.069)
Quantile 2 dummy	-0.180	-0.728**	0.021	0.017	-0.017	-0.041	-0.057*
	(0.637)	(0.033)	(0.414)	(0.524)	(0.626)	(0.168)	(0.092)
Quantile 3 dummy	0.881	0.218	0.013	0.008	-0.016	-0.069*	-0.068*
	(0.155)	(0.723)	(0.677)	(0.808)	(0.705)	(0.051)	(0.060)
Interest Coverage Ratio$_{t-1}$				-0.000*			-0.000*
				(0.087)			(0.099)
Leverage					-0.049*		-0.044
					(0.053)		(0.114)
Firm size		-0.119***				-0.013***	-0.009**
		(0.010)				(0.000)	(0.021)
Constant	0.718***	2.538***	0.088***	0.090***	0.103***	0.287***	0.242
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1072	1072	1084	1071	1075	1084	1062
Adj. R-squared	0.024	0.057	0.014	0.015	0.081	0.048	0.098