Are Renewable Energy Firms Rewarded for Being Green?

Research to the existence of a green risk factor in Renewable Energy stocks

Abstract: In this thesis, it is being researched whether a green return- and volatility factor exist. The green return factor is found with the help of the Fama-MacBeth methodology. The green volatility factor is found with the help of the GARCH(1,1) methodology with student-t innovations. From the research follows that renewable energy companies are mainly small-sized growth firms with a higher volatility than the market index. A green factor added to the Fama-French 3-factor model has significant explanatory power for the returns of renewable energy firms. Furthermore, a renewable energy index is created, which is proven to outperform the market index. Finally, the renewable energy index contains significant volatility persistence, indicating that the renewable energy index contains a significant volatility factor.

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Prologue

With finishing this thesis, I conclude my educational period at the Erasmus University Rotterdam. The last four years were very educational, and I appreciate all the opportunities I have received to fulfil my goals during my academic years. Months of hard work have been put in this thesis, and the result is visible right here. During the years at the university, my interest in Energy Finance has grown substantially. Where intentionally I put no attention to the oil price movements and the renewable energy targets that have to be met, it has now turned into my daily business. I am very proud of the thesis I have created.

I want to thank a couple of people who have supported me during the four years of study, as well as during the thesis process. First of all I would like to thank my thesis supervisor, Mehtap Kilic, for providing me with new insights and helping me with finding an interesting research topic. By providing good guidance and reacting to my questions and suggestions very quickly and positive, I could be able to create the thesis as it is now. In the same line of thought I would like to thank Ronald Huisman and ultimately the Energy Finance Institute, for working closely together with me and providing me with a full-time job now that I have completed my studies.

Finally I would like to thank my parents and sister. They have supported me from the very first day I started my studies until the writing of the very last words of this thesis. They were the helping hand during the bad times, and were just as happy as me in the good times. Furthermore, I am very grateful for providing me with shelter and a warm place to get back to after a long day of studying. Without their support, it would not have been possible to finish the studies the way I have finished it.

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1. Introduction

"The idea is taking hold that stock portfolios should be built according to investment factors, derived from the way a company performs financially and from how its stock performs, but divorced from how the company makes money" (Financial Times, 2015). This is what John Authers wrote in his column in the Financial Times on July 29, 2015. At an increasing rate factor indices are created. As an example, Authers states: "In 2014, MSCI saw the launch of 42 new Exchange Traded Funds that track its factor indexes, where there were six of those launches in 2013" (Financial Times, 2015). Not only are more and more factor indices created, the growth of the ETF's following these indices is enormous, indicating that investing in factors is getting increasingly more popular (Financial Times, 2015).

This enthusiasm is not coming out of nowhere. In a research performed by Marie Briere and Ariane Szafarz, the researchers created a contest in which they compared investing based on factors with its 'natural rival', investing based on sectors. The researchers find that based on a time period from 1963 to 2014, factor investing dominates sector investing when looking at the expected return when short-selling is allowed (Briere & Szafarz, 2016). Factor investing thus seems to outperform sector investing on the basis of expected returns. No wonder then, that the popularity of factor investing is increasing at such a high rate.

However, caution has to be warranted when picking the factors one wishes to base the investment portfolio around. As Harvey, Liu and Zhu point out in their research, at least 316 factors have been found in previous research, of which most have been proposed over the last ten years (Harvey, Liu, & Zhu, 2015). Cochrane refers to these developments as "a zoo of new factors" (Cochrane, 2011). Inevitably, data mining is present in a lot of these factors, which makes their significance in generating returns doubtful. Harvey, Liu and Zhu show that, of these 316 factors, only a few really have a significant influence on the stock returns (Harvey, Liu, & Zhu, 2015). Among those few factors are the market, size and value factors, proposed by Fama and French (Fama & French, 1992).

Another rapidly growing trend is using renewable energy sources instead of coal and gas. This rapid growth started with the introduction of the 20-20-20 targets by the European Union. These targets state that, by the year 2020, the European Union is striving to have reached a 20% reduction in gas emission compared to 1990, a 20% improvement of the energy efficiency and 20% of the energy consumption being produced from renewable sources (Council of the European Union, 2007). Recent developments show that European countries are successfully using renewable energy to fulfil these targets. In Portugal for example, 48% of their electricity is provided by renewables.

Recently, the country even ran on renewable energy alone for four days in a row (The Guardian, 2016). Around the same time, Germany announced that clean energy had powered almost all its electricity needs (Bloomberg, 2016). Last year on July 8, Denmark announced that so much power was produced by Danish windfarms that the country was able to meet its domestic electricity demand and export power to Norway, Germany and Sweden during that day (The Guardian, 2015).

Outside Europe, the popularity of renewable sources is also growing. In Australia, a poll performed by the Australia Institute indicates that 71% of Australians would be more likely to vote for a party supporting small-scale solar. On top of that, 63% of the respondents would be more likely to support a party that aims to transition to 100% renewable energy by 2030 (The Guardian, 2016). During 2015, worldwide more than twice as much money was spent on renewables than on coal and gas-fired power generation, with clean energy investments equal to 286 billion dollars (Renewable Energy Policy Network of the 21st Century, 2016). In 2015 alone, 147 Gigawatts of renewable electricity came online, which can be compared to the entire power generating capacity of Africa (The Guardian, 2016).

Still, a large amount of investments are needed in the renewable energy sector in order to sustain the current growth rate. One way to provide these investments is by investing money in the stocks of renewable energy companies. Investors are interested in the large potential economic opportunities that the transition to a renewable economy presents. However, many renewable investment opportunities do not offer optimal risk-adjusted returns on their investments (United Nations Environment Programme, 2010). It is now interesting to research whether there are certain factors available in the renewable energy sector which provide high returns, attracting capital to the sector. Alternatively, a factor that can explain the volatility of the returns could be used to reduce the risk of investing in renewable energy, thereby attracting more capital to the sector. More specifically, could there be a factor specific to the renewable energy sector, rewarding firms for being green?

1.1 Research Question and Hypotheses

In this thesis, it will be researched whether there is a factor which can explain the returns for the stocks of renewable energy firms. This will be researched with the help of the following research question:

"Do the returns of renewable energy stocks contain a green factor?"

To answer this question, a number of hypotheses are formulated. First of all, the descriptive statistics of the sample of renewable energy firms are analysed. According to previous research, stocks in the renewable energy sector are mainly growth stocks, coming from firms with a smaller size than the average stock in the market, and have a higher volatility than the average stock in the market (Chia, Goldberg, Owyong, Shepard, & Stoyanov, 2009). Therefore, the following hypothesis has been formulated:

"The sample of renewable energy stocks consists mainly of small-sized growth stocks, with high volatility compared to the market."

To research this hypothesis, data on the total returns, market capitalisation and book-to-market ratio of both the renewable energy firms and the MSCI World constituents will be gathered. Then, the descriptive statistics will be compared and tested whether there is a significant difference between the two samples.

Second, the renewable energy stocks are divided into quintiles based on their size, book-to-market ratio, profitability and the amount of investments they make. The average daily returns for these quintiles are calculated, and it is researched whether the renewable energy stocks show size and value effects similar to the market constituents. The following hypothesis is formulated:

"The returns of renewable energy stocks show a clear size and value effect."

Third, the data on the size, book-to-market ratio, profitability and investments of the sample of renewable energy firms is used in order to determine whether the Fama & French 5-factor model explains all the returns, or whether there remains a significant part of the returns unexplained. In order for a green factor to exist, a significant part of the returns should remain unexplained. The following hypothesis is used to research this:

"After controlling the returns of the renewable energy stocks for the Fama & French 5-factors, a significant part of the returns remains unexplained."

The Fama & French 5-factor model will be thoroughly explained in the Theoretical Framework section. The main methodology used to test this hypothesis is the Fama-MacBeth method. This method will be explained in the Methodology section. Using this methodology, we expect there to be a significant value for alpha after merely adjusting for the Fama & French 5-factors. Furthermore, if the R-Squared value is relatively low, this is also an indicator that there could be another factor explaining the returns of the renewable energy sample.

Next, it will be researched whether there actually is a green factor explaining the returns of renewable energy stocks. This will be done with the help of the following hypothesis:

"A green factor explains a significant part of the asset returns, after controlling for the Fama & French 5-factors."

To test this hypothesis, the models used in the hypothesis before are extended with a dummy variable indicating whether a firm belongs to the renewable energy sector or not. If this dummy variable yields a significant value, a green factor is present in the data.

Finally, it will also be researched whether there is a green volatility factor present in the data, in order to find out whether risk can be explained. Previous research will be replicated, but with a more recent and extended dataset (Sabbaghi, 2011). This last hypothesis is as follows:

"*There is significant evidence in favour of volatility persistence in the renewable energy index.*"

To test this hypothesis, a t-GARCH(1,1) model is used. This model is explained in the Methodology section. Return data for the renewable energy firms is used as the variable in this model. The coefficients and the degrees of freedom for this model will be analysed in order to state a conclusion.

1.2 Summary

The results from this thesis indicate that green energy firms are smaller than the average firm in the market, have a higher volatility, and are mainly growth stocks. Moreover, the results show that there is indeed a green factor, explaining the returns for renewable energy firms. Furthermore, there also appears to be a green volatility factor. What exactly constitutes these factors is a question left open for further research.

The remainder of this thesis is as follows. In section 2, literature on factor analysis will be analysed. Furthermore, research on the risk and return characteristics of renewable energy firms will be reviewed. Two specific articles will be reviewed extensively, since this thesis is inspired by those articles. In section 3, the gathered data and the used methods will be reviewed. In section 4, the empirical tests to test the stated hypotheses will be performed. Finally, section 5 concludes with answering the research question. Moreover, the most important findings will be summarized, restrictions on this research will be mentioned, and some recommendations for further research will be provided.

2. Literature Review

A lot of research has already been performed on factor analysis. In this section, a review of a selection of these articles will be provided. Furthermore, a selection of articles about investing in the stocks of renewable energy companies will be reviewed. Finally, an extended review will be given on the two main papers around which this thesis is built.

2.1 Factor analysis

The main research direction of this thesis is the direction of factor investing and factor analysis. A theoretical definition of factor investing is rules-based and evidence-based investing. A lot of research has already been done on this topic.

Eugene Fama and Kenneth French are considered to be the founders of factor analysis. They were the first to research the way stock returns are affected by sensitivities to different risk factors. In their most well-known article, Fama & French create a three-factor model with which stock returns can be explained. The three factors in this model are an overall market factor, a factor related to firm size and a factor related to book-to-market equity. The size-effect is found to be negative, while the book-to-market effect is found to be positive (Fama & French, 1993).

After the publication of this paper, research has been done on how to improve or extend this model. For example, a model has been proposed consisting of the market factor, a factor for investments and a return on assets factor for explaining stock returns (Chen, Novy-Marx, & Zhang, 2010). This model appeared to have results similar to the Fama & French model. Furthermore, research proves that a factor for profitability, as measured by gross profits-to-assets, has the same predicting power as the book-to-market factor, where profitable firms generate higher returns than unprofitable firms (Novy-Marx, 2013).

As a reaction to these articles, Fama & French have extended their three-factor model into a five-factor model. This model captures patterns in stock returns using a market factor and factors for size, book-to-market equity, profitability and investments. This model performs better than their three-factor model (Fama & French, 2015). David Blitz and Pim van Vliet, two researchers from Robeco, have some concerns about this extended model. They state that, although the paper does fill a gap in the finance literature, this 5-factor model still ignores momentum and low-volatility (Robeco, 2015).

2.2 Renewable Energy

Quite some research has already been performed on the risk and return characteristics in the renewable energy industry. In general, firms included in a market index seem to outperform the renewable energy firms up to 2008 (Boulatoff & Boyer, 2009). In the period hereafter, it is found that an increasing share of renewable energy firms in the investment portfolio increases portfolio performance (Masini & Menichetti, 2012). Other research finds that during periods of market stability, renewable energy indexes outperform market portfolios in terms of returns. This is associated with a higher risk level for the renewable energy indexes. This higher risk causes the returns of the renewable energy indexes to be lower than the returns on the market index (Ortas & Moneva, 2013).

Another research looked what risk factors drove the performance of German renewable energy stocks. The researchers found that the renewable energy stocks outperformed between 2004 and 2007, and that this was due to the price momentum factor, and a factor concerning the industry's positive economic outlook. However, this outperformance reversed between 2008 and 2011, indicating that renewable energy stocks are also affected by a mean reversion factor. Moreover, during this period the stocks had a strong positive sensitivity to the size factor and a high market beta (Bohl, Kaufmann, & Stephan, 2013). Furthermore, oil prices and technology stock prices appear to affect the stock prices of clean energy firms, while there is no significant relationship between carbon prices and the clean energy stock prices (Kumar, Managi, & Matsuda, 2012). Finally, it is found that company sales growth has a negative impact on the risk of renewable energy companies, while oil price increases have a positive impact on the risk (Sadorsky, 2012).

2.3 MSCI Barra

An article that is especially important for this thesis is about a research performed by various researchers of MSCI. The researchers try to find out whether there exists a green factor in the returns of renewable energy stocks (Chia, Goldberg, Owyong, Shepard, & Stoyanov, 2009). The current thesis is also trying to find whether this is the case, but a different methodology is used. Further differences between this research and the current thesis is that this thesis use a more recent sample period and a more extensive sample of renewable energy firms.

The MSCI research uses a sample of 84 stocks and uses a sample period of 2005 until 2008. First of all, the researchers use the MSCI Barra Global Equity Model to find the exposures of these stocks to various style factors compared to the global equity universe. They find that renewable energy stocks are below average in size, value and momentum, while they are above average in terms of volatility. They state that renewable energy stocks are mainly small growth stocks with a high volatility compared to the market (Chia, Goldberg, Owyong, Shepard, & Stoyanov, 2009).

The researchers also find that these factor exposures cannot fully explain the performance of the sample of renewable energy firms they use. Therefore, they use two statistical tests to check whether a green factor is present in the data. They regress the weekly returns of the full dataset on a dummy variable indicating whether a firm is green or not, to obtain an estimate of the green factor return. For consistency, they use rolling windows of 52, 104 and 156 weeks in their estimates. In the second test, in order to avoid normality assumptions, the researchers use a bootstrap methodology. They repeat the cross-sectional regressions over 1000 bootstrap runs to get reliable results. In the first method as well as the bootstrap method they find evidence on the presence of a green factor (Chia, Goldberg, Owyong, Shepard, & Stoyanov, 2009).

2.4 Sabbaghi

Another important article checks whether a green volatility factor exists (Sabbaghi, 2011). This research is also being replicated in this thesis, with as only difference a more recent sample period. Furthermore, only one renewable energy index will be researched.

The researcher uses a sample of 15 green index funds. He finds that the green returns are statistically indistinguishable from zero. Moreover, returns tend to be positive nearly half of the time and negative the other half of the time, indicating that daily green returns appear to be mean reverting to zero. Furthermore, the returns are highly volatile (Sabbaghi, 2011). A Ljung-Box test indicates that volatility clustering is present in the data. As a result, a GARCH model is used to analyse whether the green returns contain a significant volatility factor. Specifically, a GARCH(1,1) model with student-t innovations is used. Results from this model are that the green volatility depends highly on lagged volatility and lagged squared returns, and that there is significant volatility persistence in the sample. Furthermore, there are spikes in the volatility in periods where there was a market-wide event concerning green energy. The main conclusion is that there is a significant green volatility effect throughout the sample period (Sabbaghi, 2011).

3. Data & Methodology

In this section, the data and methods used will be treated thoroughly. First of all, the database consisting of all the renewable energy firms used will be discussed. This database is an extended version of the database used in my bachelor thesis. For the sake of completeness, the process of gathering the data and constructing the database will be restated in this section. Second, the financial data will be discussed. Third, the Fama-Macbeth method for estimating coefficients and their standard errors will be discussed. This is the leading methodology used in this thesis to get to the results. Finally, a quick review will be provided on GARCH modelling, especially the t-GARCH(1,1) model used in this thesis.

3.1 Creating the database

For this thesis, a database of 262 firms has been created. These firms are all actively involved in the renewable energy industry. After correcting for missing data, the database consists of 225 firms that are suitable for this research. These firms provide all the necessary data over the full sample period. All firms in the database are listed on a stock exchange. The sample period used in this research consists of the first trading day of 2012 until the last trading day in 2015.

To determine whether a firm is suitable for this research, all firms have been judged individually. This is preferred over using already existing indices for two reasons. First of all, the majority of existing indices are 'Clean Tech' indices. In these indices, a lot of technological firms are involved, for which their range of activities goes beyond the scope of this research. This makes these firms not suitable to use in the database. Using these indices might give a distorted view of the results. Second, the already existing indices do not cover the full renewable energy sector. Due to different criteria placed on these indices, most of the times only the largest firms in the sector are involved. Manually judging the suitability of the firms makes sure that the smaller public firms are also involved in the research. This makes sure that the picture of the renewable energy industry is as complete as possible (van Dam, 2015). There is a chance, however, that manually judging the firms brings about human errors. For example, it is possible that not the full population of firms in this sector have been found due to different constraints. On top of this, it is possible that certain firms are incorrectly being left out of this database or put into the database. However, for this research, a sample of 225 firms is considered sufficient to make statements about the full industry of renewable energy firms (van Dam, 2015).

3.2 The process of finding firms

The main criterion for a firm to be included in the database, is that the firm has to perform business in one of the pre-defined sub-industries. These sub-industries and their definitions are the same as those used in my bachelor thesis (van Dam, 2015). On top of the already existing sub-industries, two extra sub-industries are added to expand the database. In this sub-section, I will briefly restate the different sub-industries and their definitions. The ten different sub-industries are *biomass, wave/ocean, photovoltaic, concentrated solar, geothermal, wind, hydro, energy efficiency, energy storage,* and *other*, mainly based on a report made by the Renewable Energy Policy Network for the 21st Century (2014).

The sub-industry *biomass* consists of all firms using biological materials gathered from living, or recently living organisms (Biomass Energy Centre, 2008). The most common sources of energy from *biomass* are firewood, crop residues and animal faeces. There are, however, also deliberately grown crops with the sole purpose of being used in energy production. Alternative sources of *biomass* energy are residues from agriculture and deforestation, residues from food- and fibre processing and recycling of municipal waste. These sources can be used to provide industrial firms and households of electricity and heating (Renewable Energy Policy Network of the 21st Century, 2014).

Wave/Ocean energy refers to all the energy produced from the ocean by means of waves, tidal range, tidal streams, permanent streams and differences in temperature and salinity. *Wave* energy is mostly used to produce electricity (Renewable Energy Policy Network of the 21st Century, 2014).

Photovoltaics is the direct conversion of sunlight to electricity (Knier, 2002). Firms in this industry perform activities ranging from producing microchips to be used in the solar panels, to firms using *photovoltaics* to produce energy (van Dam, 2015).

Another sub-industry using the sun as a source of energy is *concentrated solar*. This method of energy production uses the heat of the sun. Two different methods can be distinguished. The first method uses heat of the sun to heat a liquid substance to very high temperatures. This liquid substance is being used to heat water, creating steam. This steam can then be converted into electricity (United States Energy Information Administration, 2014). The second method catches heat of the sun by using mirrors, concentrating the sunlight. The heat that originates is being used to produce electricity (Office or Energy Efficiency and Renewable Energy, 2014). Both methods are also used for heating and producing hot water (Renewable Energy Policy Network of the 21st Century, 2014).

Energy produced from *geothermal* is the heat from within the earth. Sources of this form of energy are hot water and hot rocks from beneath the surface of the earth, but also melted rocks found deeper beneath the surface, like magma (Renewable Energy World, 2015). *Geothermal* is used to provide energy through electricity and heating (van Dam, 2015).

Wind energy is being produced with the help of big wind turbines. These turbines convert the energy from the wind into electricity (Renewable Energy World, 2014). Firms in this sub-industry perform activities along the full value chain of the industry. Examples are producers of wind turbines and firms performing maintenance on wind farms (van Dam, 2015).

Hydro energy is energy produced by using flowing water. This water flows from a river through a turbine, which activates a generator, producing electricity. *Hydro* energy is a form of energy that can be stored in big reservoirs (Renewable Energy World, 2014).

Firms that provide energy *efficiency* are being defined as all firms that "work on using less energy to provide the same service". An example given by the Lawrence Berkeley National Laboratory is replacing a single pane window with an energy-efficient one. This new window prevents heat from escaping in the winter, saving energy by using less heating. Energy efficiency is not the same as energy conservation, which is reducing a service to save energy (Lawrence Berkeley National Laboratory, 2016).

Energy *Storage* firms provide a wide array of technological approaches to manage power supply. Examples of these technologies are compressed air energy storage, where compressed air is utilized to create an energy reserve, thermal, which captures heat and cold to create energy on demand, and the aforementioned hydro storage reservoirs (Energy Storage Association, 2016).

Finally, the industry *other* is a collective name for all lesser known sources of renewable energy. Examples are producing energy by using hydrogen cells and the conversion of carbon dioxide into energy (van Dam, 2015).

3.3 Market index and Risk-free rate

The sample of renewable energy firms will be compared to a market index. The MSCI World Index has been chosen as the market index, because it is the most frequently used market index when performing research on stocks. Moreover, data on all the index constituents of the MSCI World Index is used in analysing whether there are significant differences between the sample of renewable energy firms and the market. Data of a total of 1579 constituents has been gathered. Of these constituents, 43 have been removed because they operate in the renewable energy sector. A list of these firms can be found in Appendix A. After removing firms with missing data, a total of 1203 constituents remain. Since it is usual to look at the effect of an index after correcting for a risk-free rate, the returns on the daily US Treasury Bill rate have been chosen to function as a risk-free rate.

3.4 Financial data

The financial data for the sample of renewable energy firms, the market index and its constituents have been retrieved from Datastream. Datastream is a financial database with information about stocks, indices, bonds and other economic data. The data in Datastream has been provided by stock markets worldwide, national statistical bureaus and international organisations like the IMF and the OECD (van Dam, 2015). Data has been gathered on the Total Return Index, market capitalisation, book-to-market ratio, total investments and the net profit margin for all renewable energy firms and MSCI World constituents, and the Total Return Index for the MSCI World Index and US Treasury Bill.

The Total Return Index measures the theoretical value growth of a stock, assumed that all dividends are immediately reinvested to buy additional shares of the company stock. Using this data provides a more accurate image than using a price index, which merely shows the price movements of a stock. Starting with the total return index, daily returns are calculated as follows:

$$R_{i,t} = \ln\left(\frac{TRI_{i,t}}{TRI_{i,t-1}}\right) \quad (1)$$

The daily returns for stock i are calculated as the natural logarithm of the percentage difference between the Total Return Index of day t and day t-1. By taking the natural logarithm, extreme values are reduces, creating a more normal distribution within the returns.

The market capitalisation is a primary measure of the size of a firm in financial research. It is calculated as the number of shares outstanding for a firm, multiplied by the current price of those shares on the stock market. Usually, firms are ranked as large-cap, mid-cap and small-cap depending on their market capitalisation (Financial Times, 2016).

The book-to-market ratio for a firm is found by dividing the book value of equity by the market value of equity. The book value of equity is found by looking at the firm’s accounting value, so the historical value of the firm. The market value of equity is equal to the market capitalisation described above.

Finally, the Net Profit Margin is calculated as the ratio of net profits to revenues. This measurement standardizes the firm’s total profit for its total revenues. Standardizing allows comparison of a big company with a large amount of revenues, with a very small company and only little revenue.

3.5 The Fama-MacBeth Method

For running the cross-sectional regressions, the procedure introduced by Fama and MacBeth (1973) is used. This procedure will be explained in this section.

The first step in the Fama-MacBeth procedure is to find beta estimates using a time-series regression. In their analysis, Fama and Macbeth use rolling 5-year regressions (Fama & MacBeth, 1973). Equivalently, a technique with full-sample betas can be used. Since this technique has been proven to be simpler, it will be used in this thesis. This technique has been thoroughly described by Cochrane, hence is why I will refer to his book in this part of the methodology (Cochrane, 2005). To look at this first step more practical, assume we have *n* asset returns over *T* days, and *m* factors $F_{j,t}$ are used to explain the asset returns. $R_{i,t}$ refers to the excess returns on time *t* for asset *i*. Now, a set of regression equal in number to the number of assets one is testing has to be run. The outcome of these regressions tell to what extent each asset's return is affected by each factor (Hsu, 2015). This set of time series regressions look as follows:

$$R_{1,t} = \alpha_1 + \beta_{1,F_1} F_{1,t} + \beta_{1,F_2} F_{2,t} + \cdots + \beta_{1,F_m} F_{m,t} + \epsilon_{1,t} \tag{2}$$

$$R_{2,t} = \alpha_2 + \beta_{2,F_1} F_{1,t} + \beta_{2,F_2} F_{2,t} + \cdots + \beta_{2,F_m} F_{m,t} + \epsilon_{2,t} \tag{3}$$

$$\vdots$$

$$R_{n,t} = \alpha_n + \beta_{n,F_1} F_{1,t} + \beta_{n,F_2} F_{2,t} + \cdots + \beta_{n,F_m} F_{m,t} + \epsilon_{n,t} \tag{4}$$

Consequently, this set of regressions looks as follows in this thesis, where n is equal to 225 for the sample of renewable energy firms, 1203 for the sample of MSCI constituents, and 1428 for the full sample:

$$R_{1,t} = \alpha_1 + \beta_{1,F_{Market}} F_{Market,t} + \beta_{1,F_{Size}} F_{Size,t} + \beta_{1,F_{BM}} F_{BM,t} + \beta_{1,F_{Investment}} F_{Investment,t} + \beta_{1,Profitability} F_{Profitability,t} + \epsilon_{1,t}$$

$$R_{2,t} = \alpha_2 + \beta_{2,F_{Market}} F_{Market,t} + \beta_{2,F_{Size}} F_{Size,t} + \beta_{2,F_{BM}} F_{BM,t} + \beta_{2,F_{Investment}} F_{Investment,t} + \beta_{2,Profitability} F_{Profitability,t} + \epsilon_{2,t}$$

$$\vdots$$

$$R_{n,t} = \alpha_n + \beta_{n,F_{Market}} F_{Market,t} + \beta_{n,F_{Size}} F_{Size,t} + \beta_{n,F_{BM}} F_{BM,t} + \beta_{n,F_{Investment}} F_{Investment,t} + \beta_{n,Profitability} F_{Profitability,t} + \epsilon_{n,t}$$

The second step in the Fama-MacBeth approach involves running a cross-sectional regression at each point in time. Here, $\hat{\beta}_{i,F_k}$ is defined as the estimated betas for each asset for factor F_k. They are the outcomes of the regressions in the first step. In the following set of cross-sectional regressions, these variables are the same for every regression. This set of cross-sectional regressions looks as follows:

$$R_{i,1} = \alpha_1 + \gamma_{1,1}\hat{\beta}_{i,F_1} + \gamma_{2,1}\hat{\beta}_{i,F_2} + \cdots + \gamma_{m,1}\hat{\beta}_{i,F_m} + e_1 \tag{5}$$

$$R_{i,2} = \alpha_2 + \gamma_{1,2}\hat{\beta}_{i,F_1} + \gamma_{2,2}\hat{\beta}_{i,F_2} + \cdots + \gamma_{m,2}\hat{\beta}_{i,F_m} + e_2 \tag{6}$$

$$\vdots$$

$$R_{i,T} = \alpha_T + \gamma_{1,T}\hat{\beta}_{i,F_1} + \gamma_{2,T}\hat{\beta}_{i,F_2} + \cdots + \gamma_{m,T}\hat{\beta}_{i,F_m} + e_T \tag{7}$$

The $\gamma_{j,t}$ terms are regression coefficients for factor *j* on time *t*. In this thesis, the set of regressions look as follows, where T is 1044:

$$\begin{aligned} R_{i,1} = \alpha_1 &+ \gamma_{Market,1}\hat{\beta}_{i,F_{Market}} + \gamma_{Size,1}\hat{\beta}_{i,F_{Size}} + \gamma_{BM,1}\hat{\beta}_{i,F_{BM}} + \gamma_{Investments,1}\hat{\beta}_{i,F_{Investments}} \\ &+ \gamma_{Profitability,1}\hat{\beta}_{i,F_{Profitability}} + e_1 \end{aligned}$$

$$\begin{aligned} R_{i,2} = \alpha_2 &+ \gamma_{Market,2}\hat{\beta}_{i,F_{Market}} + \gamma_{Size,2}\hat{\beta}_{i,F_{Size}} + \gamma_{BM,2}\hat{\beta}_{i,F_{BM}} + \gamma_{Investments,2}\hat{\beta}_{i,F_{Investments}} \\ &+ \gamma_{Profitability,2}\hat{\beta}_{i,F_{Profitability}} + e_2 \end{aligned}$$

$$\vdots$$

$$\begin{aligned} R_{i,T} = \alpha_T &+ \gamma_{Market,T}\hat{\beta}_{i,F_{Market}} + \gamma_{Size,T}\hat{\beta}_{i,F_{Size}} + \gamma_{BM,T}\hat{\beta}_{i,F_{BM}} + \gamma_{Investments,T}\hat{\beta}_{i,F_{Investments}} \\ &+ \gamma_{Profitability,T}\hat{\beta}_{i,F_{Profitability}} + e_T \end{aligned}$$

Fama and MacBeth now suggest that the alpha and risk premiums can be estimated as the average of the cross-sectional regression estimates (Cochrane, 2005). These averages and their standard errors are the values used in the analysis in this thesis. Getting these values can be done via an ordinary least squares regression, an example of which is the following five-factor model:

$$\begin{aligned} R_{i,t} = a_i &+ b_{Market} * \gamma_{Market,t} + b_{Size} * \gamma_{Size,t} + b_{BM} * \gamma_{BM,t} + b_{Investments} * \gamma_{Investments,t} \\ &+ b_{Profitability} * \gamma_{Profitability,t} \end{aligned}$$

Statistical software programs are now necessary to estimate the values for b_m and their standard errors. EViews is used to perform these estimations.

3.6 GARCH Modelling

For researching the final hypothesis, a GARCH model is used. In order to be consistent with the research of Sabbaghi (2011), a renewable energy index is created. The daily returns for the renewable energy index are used as the input for the model. A GARCH(1,1) model is used. A GARCH(1,1) model tells us that the volatility changes with lagged shocks, but that there is also momentum in the system. The model uses the squared values of the lagged errors and the lagged volatility as inputs. The model is very popular in research, especially because it can capture long lags in the shocks with only a few parameters (Hill, Griffiths, & Guay, 2012).

The GARCH(1,1) model is extended with conditional student-t density innovations (Sabbaghi, 2011). The conditional student-t density innovations are added to the model because the daily returns data is not normally distributed. The key parameter that differentiates the t-GARCH(1,1) model used in this thesis from the usual GARCH(1,1) model is the presence of the shape parameter, which changes as the degrees of freedom increase (Sabbaghi, 2011). Formally, the model used looks as follows:

$$r_t = \sqrt{h_t z_t} \tag{8}$$

$$z_t iid \frac{t_d}{std(t_d)} \tag{9}$$

$$h_t = \omega + \alpha r_{t-1}^2 + \beta h_{t-1} \tag{10}$$

In this model, r_t is equal to the daily return residuals, h_t is equal to the volatility parameter and d is the degrees of freedom. The statistical program EViews has an in-built function to perform t-GARCH(1,1) analysis. This function will be used when performing this test.

4. Empirical Results

4.1 Full Sample Results

First of all, various hypotheses are tested on the full sample of renewable energy firms. The first hypothesis to be researched is:

"The sample of renewable energy stocks consists mainly of small-sized growth stocks, with high volatility compared to the market."

This has been examined with the following cross-sectional regression formula, where, in this example, the returns are the dependent variable:

$$Return = \alpha * Renewable + \beta * Market \quad (11)$$

In this formula, Renewable is a dummy variable yielding a value of 1 if a firm belongs to the sample of renewable energy stocks, and a value of 0 otherwise. Market is a dummy variable yielding a value of 1 if a firm belongs to the sample of firms in the market index, and a value of 0 otherwise. No constant term has been added to this formula, since the two dummy variables capture the full sample of firms analysed. By adding a constant term, this would yield perfect multicollinearity. To check whether the differences between the groups are significant, several F-tests have been performed.

Table 1 gives an overview of the outcomes for this model. The dependent variables used are the returns in percentages, market capitalisation in billion dollars as a proxy for size, the book-to-market ratio, total investments in billion dollars and the net margin as proxy for profitability. As can be seen in the table, the returns of the renewable energy stocks are negative, while the returns for the stocks in the MSCI World Index are positive. Specifically, an equally-weighted portfolio of renewable energy stocks yields a negative return of 2 basis points per day, where investing in an equally-weighted portfolio of stocks in the MSCI World Index yields a positive daily return of 4,4 basis points. The difference between the two groups is significant, meaning that renewable energy stocks significantly performed worse over the sample period. Results not disclosed in this table state that the return volatility for renewable energy firms is 11,9 basis points, where it is only 6 basis points for the MSCI World Index firms. We can thus state that renewable energy stocks have a higher return volatility than the market. Looking at the size variable, we can see that indeed the renewable energy firms are significantly smaller than the firms included in the MSCI world index. Specifically, the average size of a firm in the renewable energy sample is around 6 billion dollars, while this is 22 billion dollars for the firms included in the MSCI World Index. Finally, we can conclude that the renewable energy firms are significantly less profitable than the firms in the MSCI World Index.

Table 1: Differences in stock characteristics between renewable energy firms and firms included in the MSCI World Index.

	Returns	Size	B/M Ratio	Investments	Profit
Renewable	-0,020	5,959	0,643	1,171	-391,290
Market	0,044	22,288	0,537	5,422	-0,253
P-value	**0,000**	**0,000**	0,402	0,375	**0,001**

Next, we will check whether there is return variation within the sample of renewable energy stocks, which is caused by any of the five factors. Specifically, the focus will be on the size- and value-effect. The size effect states that smaller firms earn higher returns on average. The value effect states that firms with a higher book-to-market value earn higher returns. This will be researched with the following hypothesis:

"The returns of renewable energy stocks show a clear size and value effect."

To analyse this hypothesis, the sample is split into five quintiles, based on the four factors. For example, firms with the smallest market capitalisation are placed in the lowest quintile for the size factor, and firms with the largest market capitalisation are placed in the highest quintile. Rebalancing of the five portfolios is done every year at the beginning of April and the beginning of October. This is done for each of the four factors. An overview of the outcomes is given in table 2. This table shows the average equally-weighted monthly returns for all the quintiles. What can be seen in this table is that the quintile with the smallest values for the factors, systematically gets the lowest returns. This ranges from negative 140 basis points to negative 222 basis points. We can also see that the returns seem to be higher in the highest quintiles. However, there is no clear trend in the quintile returns. Specifically, it is not systematically the case that the returns go up when we move up a quintile. Therefore, no clear conclusion can be made based on these outcomes.

Table 2: Average monthly returns in percentages for the renewable energy stocks, sorted by size, book-to-market ratio, profitability and investments.

Smallest	**40%**	**60%**	**80%**	**Largest**
		Size		
-2,217	-0,656	0,244	0,477	0,380
		Book-to-Market Ratio		
-1,614	-0,26	-0,083	-0,328	0,512
		Profitability		
-1,584	-0,509	-0,433	0,175	0,438
		Investments		
-1,399	-0,815	0,102	0,211	0,127

It is interesting to check whether these effects have a significant influence on the returns of the renewable energy stocks. Moreover, if a part of the returns remain unexplained, this could be an indicator that there is an additional green factor which has an explanatory effect on the returns of renewable energy stocks. The following hypothesis is used to research this:

"After controlling the returns of the renewable energy stocks for the Fama & French 5-factors, a significant part of the returns remains unexplained."

Table 3 shows the time-series averages of the slopes from the daily Fama-MacBeth regressions of the renewable energy stock returns on the market return, size, book-to-market ratio, investments and profitability, and its corresponding p-value. The table also shows the values of the alpha's of the regression, as well as the R^2 for each regression. First, it can be seen that the returns of the market portfolio, the size of the firm, the amount of investments and the profitability of the firm individually have a significant influence on the cross-section of average stock returns for the renewable energy firms. Size, investments and profitability all seem to have a negative influence on the returns. This indicates that bigger firms, firms with a higher amount of investments and firms with high profitability receive lower stock returns. The size effect is consistent with the findings of Fama & French (1992). Analysing the data, it generally appears that the largest renewable energy firms are also the firms who invest the most money and are the most profitable. This could explain the common negative influence of these three factors on the returns.

Next, looking at the three- and five-factor model, we can conclude that only the slopes for the market returns and the book-to-market ratio have a significant influence on the renewable energy stock returns. Firms with a higher book-to-market ratio have lower returns, a finding inconsistent with Fama & French (1992). Looking at the data, it is the case that the smaller firms are on average the firms with a higher book-to-market ratio. Consequently, it could be the case that this variable captures the effect that the size, profitability and investment factors captured in the individual regressions.

Regarding the question whether there remains a part of the returns unexplained, the answer is twofold. First of all, for all of the regressions concerning the renewable energy firms, the alpha is insignificant. This means that there is no residual return to be explained by factors other than those included in the model. On the other hand, the model with the highest R^2 value only has a value of 40%. This means that 60% of the variation in returns remains unexplained by the model. Adding a green factor to the model could increase its R^2, indicating that it does have explanatory power for the returns of renewable energy stocks.

Table 4 shows the time-series averages of the slopes from the daily Fama-MacBeth regressions of the stock returns for the MSCI constituents on the market return, size, book-to-market ratio, investments and profitability, and its corresponding p-value.

Table 3: Average slopes (p-values) from daily regressions of renewable energy stock returns on the market return, size, book-to-market ratio, investments and profitability.

Alpha	Market	Size	B/M	Investments	Profitability	R^2
-0,000	0,469					
(0,447)	**(0,000)**					0,395
-0,000		-0,017				
(0,496)		**(0,000)**				0,022
-0,000			-0,005			
(0,554)			(0,233)			0,001
-0,000				-0,010		
(0,523)				**(0,001)**		0,012
-0,000					-0,001	
(0,609)					**(0,004)**	0,005
-0,000	0,478	0,002	-0,011			
(0,443)	**(0,000)**	(0,591)	**(0,000)**			0,402
-0,000	0,477	0,003	-0,011	-0,001	-0,000	
(0,461)	**(0,000)**	(0,580)	**(0,000)**	(0,823)	(0,437)	0,401
-0,000	0,475		-0,011			
(0,432)	**(0,000)**		**(0,000)**			0,403

Table 4: Average slopes (p-values) from daily regressions of MSCI constituents stock returns on the market return, size, book-to-market ratio, investments and profitability.

Alpha	Market	Size	B/M	Investments	Profitability	R^2
0,000	0,274					
(0,013)	**(0,000)**					0,198
0,000		-0,124				
(0,033)		**(0,001)**				0,011
0,000			0,034			
(0,027)			**(0,017)**			0,004
0,000				0,001		
(0,030)				(0,988)		0,000
0,000					-0,026	
(0,037)					**(0,001)**	0,011
0,000	0,419	-0,325	0,147			
(0,006)	**(0,000)**	**(0,000)**	**(0,000)**			0,356
0,000	0,417	-0,339	0,148	0,065	-0,006	
(0,005)	**(0,000)**	**(0,000)**	**(0,000)**	(0,094)	(0,316)	0,357

As can be seen, the factors for the market, size, book-to-market and profitability are all individually significant. When looking at the three-factor model, the same conclusions can be drawn as Fama and French (1992). All three factors have a significant influence on the returns. Specifically, larger firms yield lower returns, and firms with a higher book-to-market ratio receive higher returns.

Moreover, looking at the five-factor model, more or less the same conclusions can be drawn as Fama and French (2015). Again, the factors for the market, size and book-to-market have a significant influence. The sign of these factors is also consistent with their research. However, the factors for investments and profitability do not have a significant influence on the stock returns.

To find out whether a green factor is present in the data, the following hypothesis has been formulated:

"A green factor explains a significant part of the asset returns, after controlling for the Fama & French 5-factors."

The samples of the renewable energy stock and MSCI constituents are added together to create one big sample on which to perform the analysis. Since it is not possible to gather data on, for example, the amount of carbon dioxide emission or some sort of green rating, it is analysed whether a dummy-variable yielding a value of 1 when a firm belongs to the renewable energy sample has a significant influence on the stock returns. If this is the case, the returns for renewable energy stocks do have an additional factor explaining their returns. The outcomes for this analysis are in table 5. Panel A shows the outcomes of the analysis without the green factor included, whereas panel B shows the outcomes including the green factor.

First, analysing panel A shows that the results are comparable with the results from Fama and French (1992). Again, factors for the market, size, book-to-market ratio and profitability have a significant influence on the stock returns of the full sample. The three factors in the three-factor model also all have a significant influence on the stock returns, with signs consistent with those found in Fama & French (1992). However, the alpha in this three-factor model is significant. This indicates that there is some other factor explaining a part of the returns, which could possibly be the green factor. Finally, panel A shows that the two added factors in the five-factor model have no significant influence on the stock returns. Therefore we can focus on the three-factor model only.

Table 5

Panel A: Average slopes (p-values) from daily regressions of the full sample of stock returns on the market return, size, book-to-market ratio, investments and profitability.

Alpha	Market	Size	B/M	Investments	Profitability	R^2
0,000	0,351					
(0,040)	**(0,000)**					0,278
0,000		-0,090				
(0,092)		**(0,011)**				0,005
0,000			0,024			
(0,082)			**(0,033)**			0,003
0,000				-0,007		
(0,089)				(0,859)		0,000
0,000					-0,014	
(0,083)					**(0,009)**	0,006
0,000	0,402	-0,212	0,063			
(0,034)	**(0,000)**	**(0,000)**	**(0,000)**			0,343
0,000	0,401	-0,210	0,063	0,009	-0,002	
(0,033)	**(0,000)**	**(0,000)**	**(0,000)**	(0,792)	(0,651)	0,342

Panel B: Average slopes (p-values) from daily regressions of the full sample of stock returns on the market return, size, book-to-market ratio, investments, profitability and a green factor.

Alpha	Market	Size	B/M	Investments	Profitability	Green	R^2
0,000	0,375					-0,184	
(0,158)	**(0,000)**					**(0,000)**	0,293
0,000		-0,099				0,059	
(0,065)		**(0,006)**				(0,186)	0,006
0,000			0,030			0,075	
(0,051)			**(0,011)**			(0,105)	0,005
0,000				-0,011		0,038	
(0,073)				(0,787)		(0,390)	0,000
0,000					-0,014	0,035	
(0,068)					**(0,010)**	(0,419)	0,005
0,000	0,41	-0,205	0,058			-0,084	
(0,073)	**(0,000)**	**(0,000)**	**(0,000)**			**(0,030)**	0,346
0,000	0,409	-0,202	0,058	0,012	-0,003	-0,086	
(0,070)	**(0,000)**	**(0,000)**	**(0,000)**	(0,726)	(0,599)	**(0,027)**	0,345

Panel B includes the green factor in every model. Looking at this panel, we can see that the inclusion of this green factor changes the coefficients of the factors slightly in every model, but the sign and the significance of the factors remains the same. Therefore, in the analysis, it is sufficient to look at the three-factor model and compare the model without the green factor to the model with the green factor. What can be seen is that the green factor has a significant negative influence. So, correcting for the market-, size- and book-to-market factors, being a firm active in the renewable energy industry yields lower returns than the other firms in the sample. This is consistent with a finding done in my bachelor thesis, stating that there are a lot of bad companies within the sector (van Dam, 2015). Adding the green factor has as a consequence that the alpha of this model is no longer significant. This means that the remaining return to be explained by the model is explained by the added green factor. Finally, the R-squared increases slightly when adding the green factor.

4.2 Renewable Energy Index Returns

These results, especially the negative sign of the green factor, are of no good to the renewable energy sector. Seeing these results, the conclusion would be to avoid investing in the renewable energy sector, since on average its returns are lower than those for the market index. However, it is possible to create a profitable renewable energy investment strategy. An example of a profitable renewable energy investment strategy is a theoretical stock index I have created in cooperation with the Erasmus University's Energy Finance Institute, the Renewable Energy EFI-25 index. I will describe the way this index is created, and perform an empirical test with the help of the return data of this index.

All the renewable energy firms used in the database for this thesis are eligible to be used in the index. The only constraint placed on the firms is that a firm is not used in the index if it has an above-average amount of returns equal to zero over the 4-year sample period. This way, we make sure that only relatively liquid stocks are used in the index. The remaining 187 firms are sorted by market capitalization. The top 50 percent of biggest firms are now used to create the index. The index itself consists of 25 firms and is equally-weighted. The firms that constitute the final index are selected by using a model with a constant term (alpha), market returns and the change in oil prices. Every half-year, the 25 renewable energy firms with the highest alpha over that half-year period are selected. It is rebalanced half-yearly, at the end of March and the end of September.

This index will be used in the analysis of the final hypothesis. Since we have found that the sample of renewable energy firms has a higher return volatility than the market, perhaps there is a green volatility factor as well. If this is the case, it could be made possible to control the amount of risk that comes with investing in renewable energy. This could attract more funds to the sector. The last hypothesis therefore is as follows:

"There is significant evidence in favour of volatility persistence in the renewable energy index."

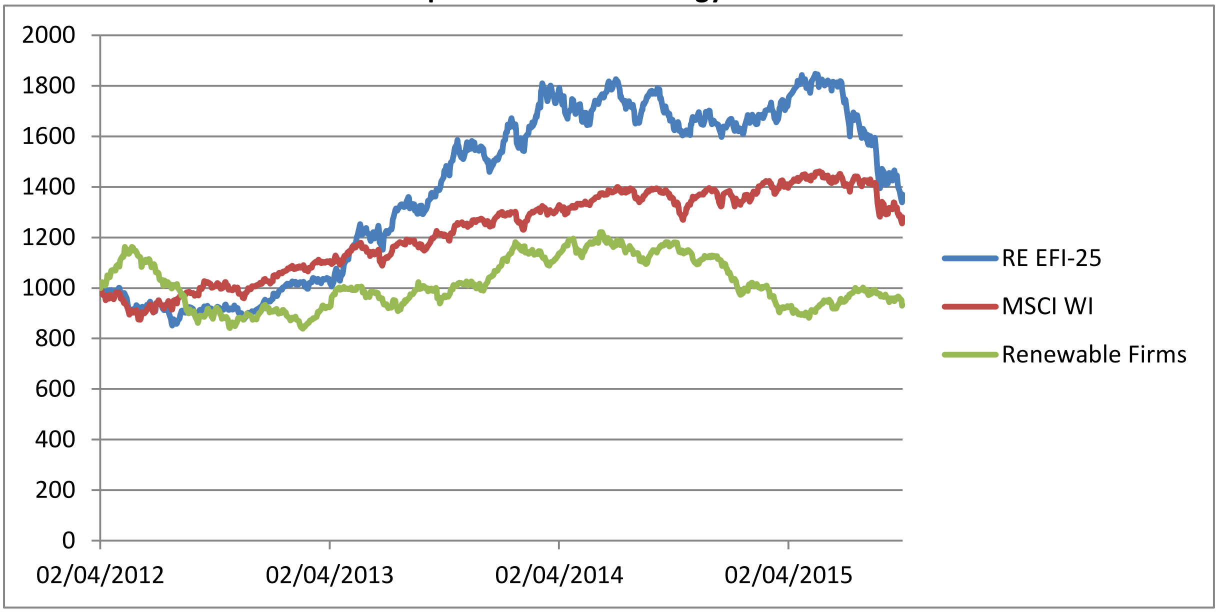
First of all, the descriptive statistics are presented in table 6. To get a clear view of the descriptive statistics of the index, the values for the renewable energy index are compared to the full sample of renewable energy firms. All values are in percentages. As can be seen from the table, the renewable energy index yields a positive daily return of 4 basis points, compared to a negative daily return of 2 basis points for the sample of renewable energy firms. The median for both samples is higher than the average value, indicating that the returns are negatively skewed. Moreover, the extreme returns are wider for the index than for the full sample. Together with the standard deviation, this indicates that investing the index is more risky than in the full sample. This is mainly because in the full sample, diversification benefits are bigger compared to a selection of 25 high-return companies.

Table 6: Descriptive statistics of the renewable energy index and the full sample of renewable energy firms

	Mean	Median	Maximum	Minimum	Std. Dev.
RE-EFI 25	0,040	0,119	3,867	-4,280	1,004
Renewable	-0,020	0,031	3,550	-3,495	0,780

Despite the higher risk, the renewable energy index performs good compared to the full sample and the MSCI World index during the sample period. Figure 1 shows this graphically. In the figure, the cumulative returns for these three samples are shown. As a starting point, it is assumed that an amount of 1000 euro is invested in the three indexes. The graph shows the value of the portfolio assuming that the index is held throughout the full sample. As can be seen, the renewable energy index outperforms both the market index and the full set of renewable energy firms. The higher volatility is also visible, indicated by the amount of variation in the curve. Investing an amount of 1000 euro in the renewable energy index at the start of the sample period yields a portfolio value of 1370 euro at the end of the sample. Comparably, investing this amount in the MSCI World index yields a portfolio value of 1280 euro, while investing in the full set of renewable energy firms constitutes in a loss. Where investing in the full sample of renewable energy firms is unprofitable, it is very profitable to invest in an index consisting of a sub-sample of renewable energy firms.

Figure 1: Cumulative returns of the Renewable Energy index, the MSCI World index and the full sample of renewable energy firms



Before estimating the GARCH model, it is necessary to test the returns for the renewable energy index for volatility clustering with the Ljung-Box test (Sabbaghi, 2011). This is done by testing the index for autocorrelation in the squared return series. Results for this test are presented in Appendix B. It appears that the p-values in this Ljung-Box test are near zero up and until the 36th lag. Consistent with the research performed by Sabbaghi, we can reject the null of no serial correlation, which suggests the presence of volatility clustering in the index (Sabbaghi, 2011). This justifies the use of the t-GARCH(1,1) model as described in the methodology.

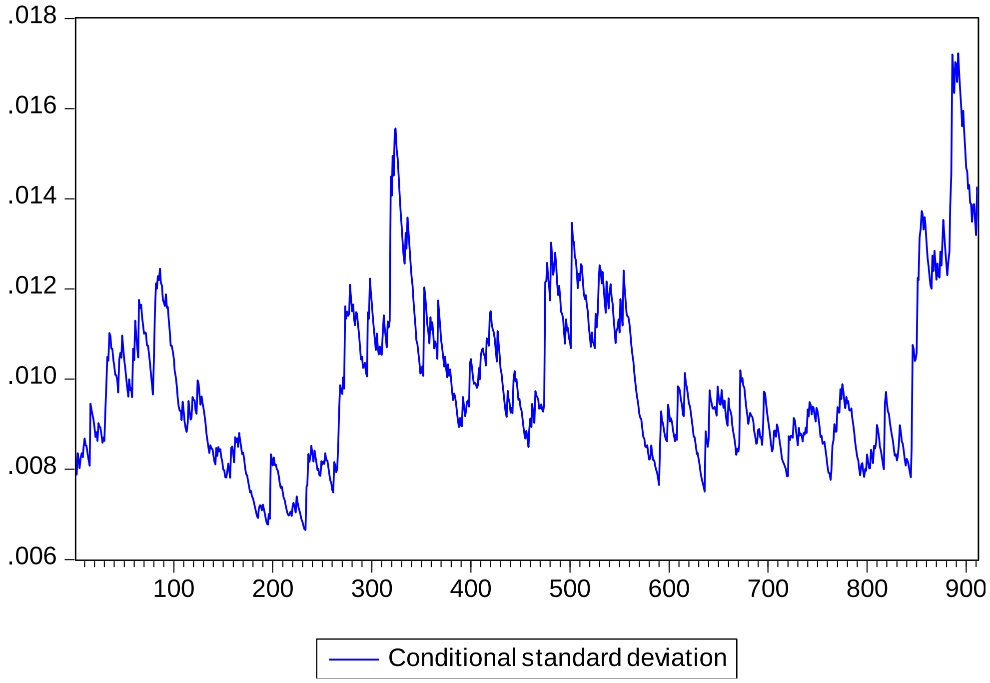
Table 7 reports the parameter estimates for the t-GARCH(1,1) model used. The two GARCH coefficients α and β are highly significant, which suggests that current volatility depends highly on lagged volatility and lagged squared returns, consistent with previous research (Sabbaghi, 2011). The β-estimate is greater than the α-estimate, suggesting that the conditional volatility of the day before is the most important indicator of today's volatility. To test whether there is persistence in the volatility process, the sum of the α and β coefficients must sum to a value around 1 (Sabbaghi, 2011). In this case, the two coefficients sum to approximately 0.98, which is sufficiently close to 1 to conclude that there indeed is a high degree of volatility persistence in the renewable energy index. These results are consistent with previous research (Sabbaghi, 2011). Finally, the degrees of freedom parameter is also highly significant. Since this parameter functions as a shape parameter, this is evidence that estimating the volatility with student-t innovations is important. Given the significance of the coefficients in the model, the conclusion can be made that a significant volatility factor exists in the renewable energy index.

Table 7: Coefficients, degrees of freedom and P-values of the t-GARCH(1,1) model on the conditional volatility of the renewable energy index.

RE EFI-25	Coefficient	P-Value
ω	0,000	(0,144)
α	0,051	**(0,002)**
β	0,934	**(0,000)**
d	9,974	**(0,004)**

Finally, a graph showing the conditional volatilities resulting from the t-GARCH(1,1) model for the renewable energy index is shown in figure 2. It is shown that the conditional volatility tends to mean revert to a value around 1%. Comparing this data to the data of Sabbaghi (2011), there are no real spikes seen in the data. Where the conditional volatility in his research shows a spike up to 6% from an average value of 1.5%, the highest spike in the current research is around 1.8%. Therefore we can conclude that the current sample period is a relatively stable period in terms of sudden market events in the renewable energy sector.

Figure 2: Conditional volatilities for the renewable energy index



5. Conclusion

In this thesis, research is done to the return and risk characteristics of the stocks of firms in the renewable energy industry. More specifically, research is done to the existence of some sort of green factor, with the help of the following research question:

"Do the returns of renewable energy stocks contain a green factor?"

In order to answer this question, a sample of 225 renewable energy firms is used. With the help of the Fama-MacBeth methodology, it is found that a green factor does exist. This green factor is found via a dummy variable giving a value of 1 if a firm is in the sample of renewable energy firms and a value of 0 if it is not. However, the sign of the green factor is negative, indicating that the sample of renewable energy firms yields a lower daily average return than the market.

Despite these findings, there are still profitable investment opportunities in the renewable energy industry. In this paper, an index is created by selecting the 25 firms with the highest alpha from a regression model, with rebalancing occurring semi-annually. This renewable energy index outperforms the market index as well as the full sample of renewable energy firms. Furthermore, it is found that this index contains a significant volatility factor. This indicates that there is significant volatility persistence in this renewable energy index.

There are some limitations to the research performed. First of all, human error could be present in the creation of the database of renewable energy firms. There is a probability that there are still renewable energy firms that have been overlooked in the process of creating the database. Moreover, it is possible that certain sub-industries are relatively unknown. This could cause the omission of this complete sub-industry and consequently the companies in this industry. Finally, the proposed method for creating the renewable energy index is very straight-forward. Most important, the method lacks constraints which are normally placed on stock indexes, for example the requirement that a firm is at least a minimum number of months publicly traded.

Opportunities for further research are very rich, given that the renewable energy industry is a relatively new industry. First of all, the current database can be extended and improved. It is very likely that not all renewable energy companies are included in the database. Furthermore, the same research could be repeated, but with a different methodology. The methods used in this research are not the only methods suitable for performing this research. Therefore, using different methods could be useful. Finally, what constitutes the actual green return and volatility factors remains unclear. It would be recommended to replace the green dummy variable with firm data. Examples are carbon dioxide emission per company, or some kind of green rating.

Bibliography

Biomass Energy Centre. (2008). *What is Biomass?* Retrieved on April 30, 2016, from Website of Biomass Energy Centre: http://www.biomassenergycentre.org.uk/portal/page?_pageid=76,15049&_dad=portal

Bloomberg. (2016, May 16). Germany just got almost all of its power from Renewable Energy. *Bloomberg*.

Bohl, M., Kaufmann, P., & Stephan, P. (2013). From hero to zero: Evidence of performance reversal and speculative bubbles in German renewable energy stocks. *Energy Economics*, 40-51.

Boulatoff, C., & Boyer, C. (2009). Green Recovery: How are Environmental Stocks doing? *The Journal of Wealth Management*, 9-20.

Briere, M., & Szafarz, A. (2016). Factor-Based v. Industry-Based Asset Allocation: The Contest. *Working Paper*, 1-70.

Chen, L., Novy-Marx, R., & Zhang, L. (2010). An Alternative Three-Factor Model. *Working Paper*.

Chia, C., Goldberg, L., Owyong, D., Shepard, P., & Stoyanov, T. (2009). Is there a green factor? *Journal of Portfolio Management, Vol. 35(3)*, 34-40.

Cochrane, J. (2005). *Asset Pricing.* New Jersey: Princeton University Press.

Cochrane, J. (2011). Presidential Address: Discount Rates. *Journal of Finance. Vol 66*, 1047-1108.

Council of the European Union. (2007). *Presidency Conclusions.* Brussel.

Energy Storage Association. (2016). *Energy Storage Technologies.* Retrieved on May 2, 2016, from Website of Energy Storage Association: energystorage.org/energy-storage/energy-storage-technologies

Fama, E., & French, K. (1992). The cross-section of expected stock returns. *Journal of Finance*.

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

Fama, E., & French, K. (2015). A five-factor asset pricing model. *Journal of Financial Economics*, 1-22.

Fama, E., & MacBeth, J. (1973). Risk, Return and equilibrium: Empirical tests. *The Journal of Political Economy*, 607-636. Vol. 81 (3).

Financial Times. (2015, July 29). *Factor investing proves useful to some.* Retrieved on June 31, 2016, from Website of the Financial Times: https://next.ft.com/content/b04138b2-3570-11e5-b05b-b01debd57852

Financial Times. (2015, January 28). *Why factor investing is flavour of the month.* Retrieved on June 31, 2016, from Website of the Financial Times: http://www.ft.com/cms/s/0/66c87b7a-a6fd-11e4-9c4d-00144feab7de.html#axzz4AGCpzZ3f

Financial Times. (2016). *Definition of market capitalisation.* Retrieved on May 2, 2016, from Website of Financial Times: lexicon.ft.com/Term?term=market-capitalisation

Harvey, C., Liu, Y., & Zhu, H. (2015). ... and the Cross-Section of Expected Returns. *Review of Financial Studies*.

Hill, R., Griffiths, W., & Guay, C. (2012). *Principles of Econometrics.* Hoboken: John Wiley and Sons, Inc.

Hsu, J. (2015). *Fama MacBeth Estimation.* Retrieved on May 17, 2016, from Website of Jason Hsu: http://www.jasonhsu.org/uploads/1/0/0/7/10075125/two_stage_fama_macbeth.pdf

Knier, G. (2002). *How do Photovoltaics work?* Retrieved on 30 April, 2015, from Website of NASA: http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/

Kumar, S., Managi, S., & Matsuda, A. (2012). Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis. *Energy Economics*, 215-226.

Lawrence Berkeley National Laboratory. (2016). *What's Energy Efficiency?* Retrieved on May 2, 2016, from Website of Lawrence Berkeley National Laboratory: eetd.lbl.gov/ee/ee-1.html

Masini, A., & Menichetti, E. (2012). The impact of behavioural factors in the renewable energy investment decision making process: Conceptual framework and empirical findings. *Energy Policy*, 28-38.

Novy-Marx, R. (2013). The other side of value: The gross profitability premium. *Journal of Financial Economics*, 1-28.

Office or Energy Efficiency and Renewable Energy. (2014). *Concentrating Solar Power.* Retrieved on April 30, 2016, from Website of Energy.gov: http://energy.gov/eere/sunshot/concentrating-solar-power

Ortas, E., & Moneva, J. (2013). The Clean Techs equity indexes at stake: Risk and return dynamics analysis. *Energy*, 259-269.

Renewable Energy Policy Network of the 21st Century. (2014). *Renewables 2014: Global Status Report.* Paris.

Renewable Energy Policy Network of the 21st Century. (2016). Renewables 2016: Global Status Report. *REN21*.

Renewable Energy World. (2014). *Hydropower.* Retrieved on May 2, 2016, from Website of Renewable Energy World: http://www.renewableenergyworld.com/hydropower/tech.html

Renewable Energy World. (2014). *Wind Energy.* Retrieved on May 2, 2016, from Website of Renewable Energy World: http://www.renewableenergyworld.com/wind-power/tech.html

Renewable Energy World. (2015). *Geothermal Energy.* Retrieved on April 30, 2016, from Website of Renewable Energy World: http://www.renewableenergyworld.com/geothermal-energy/tech.html

Robeco. (2015, October 21). *Fama-French 5-factor model: why more is not always better.* Retrieved on June 28, 2016, from Website of Robeco: http://www.robeco.com/en/professionals/insights/quantitative-investing/factor-investing/2015/fama-french-5-factor-model-why-more-is-not-always-better.jsp

Sabbaghi, O. (2011). The behaviour of green exchange-traded funds. *Managerial Finance, Vol. 37 (5)*, 426-441.

Sadorsky, P. (2012). Modeling renewable energy company risk. *Energy Policy*, 39-48.

The Guardian. (2015, July 10). Wind power generates 140% of Denmark's electricity demand. *The Guardian*.

The Guardian. (2016, May 31). Most voters support transition to 100% renewable energy, says Australia Institute. *The Guardian*.

The Guardian. (2016, May 18). Portugal runs for four days straight on renewable energy alone. *The Guardian*.

The Guardian. (2016, June 1). Renewable Energy smashed global records in 2015, report shows. *The Guardian*.

United Nations Environment Programme. (2010). *Global investor statement on climate change: Reducing risks, seizing opportunities & closing the climate investment gap.*

United States Energy Information Administration. (2014, November 14). *Solar Explained - Solar thermal power plants.* Retrieved on April 30, 2016, from Website of EIA: http://www.eia.gov/energyexplained/?page=solar_thermal_power_plants

van Dam, P. (2015). Beleggen in Duurzame Energie. *Bachelor Thesis*.

Appendix A: Renewable energy firms in the MSCI World Index

This table gives an overview of the renewable energy firms which are excluded from the MSCI World Index. To make sure that there are no duplicate values in this research, these firms have been removed from the sample of MSCI constituents.

ABB Limited	AES Corporation	Alstom
BASF	Calpine	Centrica PLC
Contact Energy	Dominion Resources	Duke Energy
DuPont	E.On SE	Electric Power Development
Endesa	Enel Green Power	Exelon
FirstEnergy Corporation	Fortum	Honeywell
Iberdrola SA	Intertek	Johnson Controls
Kansai Electric Power	Koninklijke DSM	Kurita Water Industries
Kyushu Electric Power	Mitsubishi Electric	NextEra Energy Partners
Novozymes	NRG Energy	Quanta Services
RWE AG	SAFT Groupe	Schneider Electric
SGS SA	Siemens	Skanska Energy
SSE PLC	Tesla Motors	Tokyo Electric Power
Umicore	United Utilities Group	Vestas Wind Systems
Xylem Corporation		

Appendix B: Results of the Ljung-Box test for volatility clustering

Sample: 1 912
Included observations: 912

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.|*		.|*		1	0.187	0.187	32.073	0.000
.|		.|		2	0.011	-0.025	32.187	0.000
.|		.|		3	-0.049	-0.048	34.404	0.000
*|		*|		4	-0.088	-0.072	41.556	0.000
.|		.|		5	-0.053	-0.025	44.166	0.000
.|		.|		6	0.011	0.024	44.283	0.000
.|		.|		7	0.021	0.008	44.698	0.000
.|		.|		8	0.066	0.054	48.748	0.000
.|		.|		9	0.057	0.033	51.782	0.000
.|		.|		10	0.022	0.008	52.225	0.000
.|		.|		11	0.004	0.007	52.239	0.000
.|		.|		12	-0.001	0.010	52.240	0.000
.|		.|		13	0.005	0.015	52.261	0.000
.|		.|		14	0.042	0.044	53.894	0.000
.|		.|		15	0.009	-0.008	53.968	0.000
.|		.|		16	-0.016	-0.020	54.212	0.000
.|		.|		17	0.001	0.007	54.212	0.000
.|		.|		18	0.006	0.008	54.243	0.000
.|		.|		19	-0.047	-0.052	56.316	0.000
.|		.|		20	0.012	0.026	56.445	0.000
.|		.|		21	-0.000	-0.010	56.445	0.000
.|		.|		22	-0.016	-0.022	56.672	0.000
.|		.|		23	-0.016	-0.019	56.901	0.000
.|		.|		24	0.003	0.009	56.910	0.000
.|		.|		25	0.047	0.049	58.971	0.000
.|		.|		26	0.039	0.017	60.388	0.000
.|		.|		27	-0.013	-0.025	60.559	0.000
.|		.|		28	-0.008	0.003	60.624	0.000
.|		.|		29	0.017	0.030	60.893	0.000
.|		.|		30	-0.062	-0.064	64.552	0.000
.|		.|		31	-0.050	-0.029	66.939	0.000
.|		.|		32	-0.057	-0.046	69.965	0.000
.|		.|		33	0.002	0.020	69.968	0.000
.|		.|		34	0.054	0.035	72.737	0.000
.|		.|		35	0.071	0.039	77.497	0.000
.|		.|		36	-0.018	-0.044	77.790	0.000