Universidade Europeia

2022

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CLEAN ENERGY ETFs - A NEW SUSTAINABLE TREND

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Master thesis presented to the Social Sciences and Technology Faculty of Universidade Europeia, to fulfill the requirements necessary to obtain the Master's degree in Management and Business Strategy carried out under the scientific guidance of Doctor Maria Albertina Barreiro Rodrigues, Assistant Professor of Social Sciences and Technology Faculty of Universidade Europeia.

To my Family.

Acknowledgments

This thesis marks the end of a two-year journey of a Master’s Degree in Management and Business Strategy at Universidade Europeia.

I use this opportunity to express my gratitude to my supervisor, Doctor Maria Albertina Barreiro Rodrigues, for her invaluable guidance and suggestions

To my family a special thank you for supporting me in this adventure. Without them, this work would have been unattainable.

"Formal education will make you a living; self-education will make you a fortune." -
Jim Rohn

"Compound interest is the eighth wonder of the world. He who understands it earns it.
He who doesn't pays it." - *Albert Einstein*

Keywords Exchange-Traded Funds; Clean Energy; ESG; Geometric Brownian Motion; Monte Carlo Simulation

Abstract Sustainability is becoming a very important topic, which reflects the collective awareness to not degrade even more our dear planet. Finance is also becoming more democratic and people can now invest in the stock market for as little as 10 Euros. Additionally, the sustainability issue has been impacting the finance industry through environmental, social, and governance initiatives (ESG). This master thesis analyzes the future performance of a selected group of clean energy Exchange-Traded Funds (ETFs) and compare them to a representative benchmark that is the *MSCI World Index*. This study tries to formulate if it is better to invest in a fund that represents the majority of the companies in developed countries, in a broad ESG fund that encompasses some environmental categories, or whether is it better to support the different environmental categories individually. To do so, past performances are analyzed - from January 1st, 2010 to December 31st, 2021 - and by the use of the geometric mean and standard deviation, we analyze the expected future valuations. The methodology used to create the future ETFs' price is the Geometric Brownian Motion (GBM), which is retested several times with the help of a Monte Carlo Simulation. The key findings of this thesis are that an investment in Invesco Water Resources and in World Index can provide a positive and steady return over the period studied. Furthermore, if we invested in Invesco Solar and in iShares Global Clean Energy, it can constitute a poor investment decision since both underperform the broad market. This work contributes to the existing literature regarding sustainable finance and investing in a specific World Index and in some selected exchange-traded funds that are exposed to the broad clean energy environment and in some specific categories, such as solar, wind, water, and lithium. The results provided help those who wish to have a degree of exposure to clean energy funds in their portfolio, only regarding the past performance of these funds and through multiple simulations, project the outcome into the future.

Palavras-Chave Exchange-Traded Funds; Energia limpa; ESG; Geometric Brownian Motion; Simulação Monte Carlo

Resumo

A sustentabilidade está a tornar-se um tema muito importante, o que reflete a consciência coletiva de não degradar ainda mais o nosso querido planeta. As finanças estão também a tornar-se mais democráticas e as pessoas podem agora investir na bolsa de valores com apenas 10 euros. Além disso, a questão da sustentabilidade tem vindo a ter impacto na indústria financeira através de iniciativas ambientais, sociais e de governação (ESG). Esta tese de mestrado analisa o desempenho futuro de um grupo selecionado de fundos de energia limpa negociados em bolsa (ETFs) e compara-os com um *benchmark* de referência que é o *MSCI World Index*. Este estudo tenta formular se é melhor investir num fundo que representa a maioria das empresas nos países desenvolvidos, num fundo que abranja todas as categorias ambientais, ou se é melhor apoiar as diferentes categorias ambientais individualmente. Para tal, são analisados os desempenhos passados - de 1 de Janeiro de 2010 a 31 de Dezembro de 2021 - e, através da utilização da média geométrica e do desvio padrão, analisamos as avaliações futuras esperadas. A metodologia utilizada para criar o futuro preço das ETFs é o *Geometric Brownian Motion* (GBM), que é testado várias vezes com a ajuda de uma Simulação Monte Carlo. As principais conclusões desta tese são que um investimento *na Invesco Water Resources* e no *MSCI World Index* podem proporcionar um retorno positivo e constante ao longo do período estudado. Além disso, se investirmos na *Invesco Solar* e no *iShares Global Clean Energy*, pode constituir uma má decisão de investimento, uma vez que ambos têm um desempenho inferior ao mercado. Este trabalho contribui para a literatura existente sobre finanças sustentáveis e o investimento num Índice Mundial específico e em alguns fundos de troca selecionados que estão expostos ao amplo ambiente de energia limpa e em algumas categorias específicas, tais como solar, eólico, água e lítio. Os resultados fornecidos ajudam aqueles que desejam ter um grau de exposição aos fundos de energia limpa na sua carteira, tendo em conta o desempenho passado destes fundos e através de múltiplas simulações, projetam os resultados para o futuro.

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Table of Abbreviations and Acronyms

AP - Authorized Participant

AUM - Assets Under Management

BEV - Battery Electric Vehicle

BM - Brownian Motion

BTC - Bitcoin

CEO - Chief Executive Officer

CEP - Corporate Environmental Performance

CER - Corporate Environmental Responsibility

CSR - Corporate Social Responsibility

EFV - Expected Future Value

ESG - Environmental Social and Governance

ETF - Exchange Traded Funds

ETP - Exchange Traded Products

EV - Electric Vehicle

FCEV - Fuel Cell Electric Vehicle

GBM - geometric brownian motion

GHG - Greenhouse gas

GHGE - Greenhouse gas emissions

HEV - Hybrid Electric Vehicles

NAV - Net Asset Value

OTEC - Ocean Thermal Energy Conversion

PHEV - Plug-in Hybrid Electric Vehicle

PRI - Principles for Responsible Investing

RES - Renewable Energy Sources

RWT - Random Walk Theory

S&P - Standard & Poor's

SEC - Securities and Exchange Commission

SPDR - Standard & Poor's Depositary Receipts

VIPERs - Vanguard Index Participation Equity Receipts

WEBS - World Equity Benchmark Shares

WTI - West Texas Intermediate

Introduction

"Gold is money. Everything else is credit." - *J. P. Morgan*

In February 2020 global economies were pushed into a recession, the S&P500 entered a bear market territory, the unemployment rate hit a record high, since the subprime crisis, and WTI crude futures traded negative for a brief period (Bouhali et al., 2021; Organisation for Economic Co-operation and Development, 2021).

What started as a virus in China, due to globalization, quickly spread to every single country and became a mass pandemic never seen since the Spanish flu. It brought about a large number of deaths along with social and economic restrictions.

To counter this crisis, central banks around the world decided to carry out special monetary programs. In the United States, the Federal Reserve started an aggressive quantitative easing program of expanding its balance sheet through the purchase of treasury securities and mortgage-backed securities as well as increasing their total money supply M1, which is composed of currency and savings deposits, by 11.5 Trillion USD, over a month (Federal Reserve, 2021; FRED, 2022). The European Central Bank also started the PEPP[1] where a total of 1.6 Trillion EUR – as of December 2021 - were bought in bonds, commercial paper, and public sector securities (ECB, 2022).

This "easy printing money" policy was far from indifferent to investors that "bought the dip" one month later for exceptional returns on US-denominated assets (Tradingview, 2022). Furthermore, a disruptive market had emerged – the small retail investor was starting to speculate on the next big market move, where they gathered in.

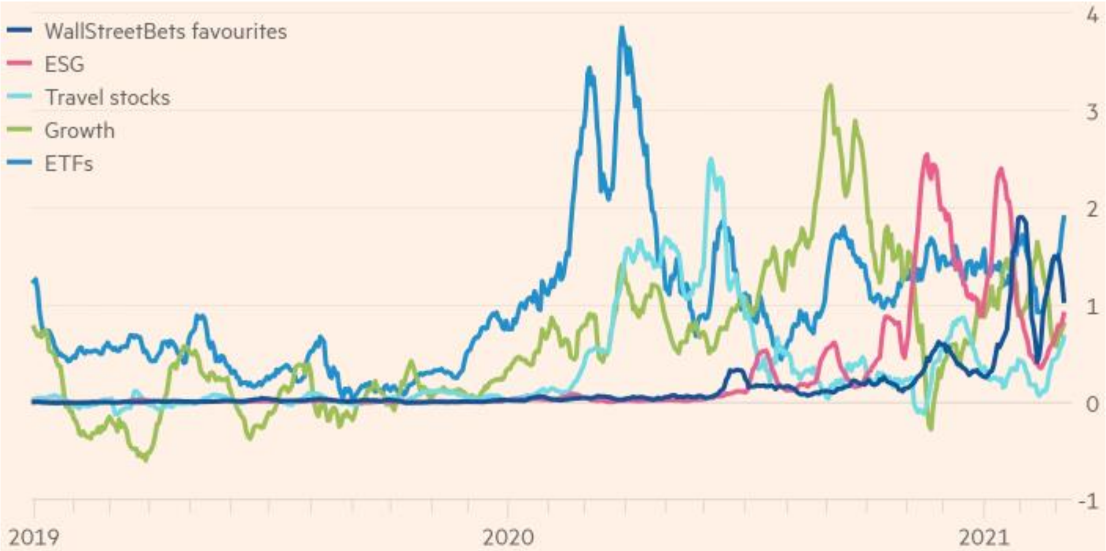
A Financial Times (2021) article cites that "degenerates" - what they call themselves - like to use social media as investment advisory and speculate on the next big move. A few examples started to happen in 2021 such as the Gamestop and AMC saga in the stock market and the rise of Dogecoin and Shiba Inu in the crypto market.

[1] Pandemic emergency purchase programme

The application of Modern Portfolio Theory to modern finance, stating that while investors consider expected returns somewhat desirable they acknowledge the return's variance as something undesirable, thus creating a well-diversified portfolio is key to offer as little variance as possible, which is mostly dependent on the investor's risk aversion (Markowitz, 1952). This is incompatible with these new investment ideas, because these social investors do not take into account the downside risk a volatile stock may have.

Fabozzi and Grant (2001, pp. 18–19) complement that a well-diversified portfolio is key to "reduce portfolio risk without sacrificing return" and is "a goal investors should seek". One possible deduction, applying this concept to retail investment, in recent years, is that inflows are being shifted towards Exchange-Traded Funds (ETFs), growth, and ESG securities, as represented in Figure 1.

Figure 1 Retail trading investing themes (inflows in Billion[2] USD)



Source: Financial Times, Vanda Research (2021)

Since Environmental Social and Governance (ESG) initiatives are a topic in which governments and corporations are researching and carrying out, this thesis would favor the research of ESG development, sustainable finance, and the stock market.

[2] 1 Billion = 1,000,000,000

The choice of the green energy sector is evident due to its growing popularity and is a topic very debated because of the benefits it provides to all economic agents. Investing in renewable energy means mitigating the use of fossil fuel production, the main contributor to air pollution and global warming. Also, other benefits include savings in costs for the end-user, improvement in air quality and human wellness, and improvement in energy efficiency (U.S. EPA, 2018).

So, to further explore this renewable sector this thesis looks to determine if an investment in a fund - representing the majority of companies on developed countries that are publicly traded - is better than investing in a broad ESG fund that encompasses all the environmental categories, or is it better to support the different environmental categories individually.

In this thesis, a look into key Exchange-Traded Funds on the ESG thematic is taken. The primary goal is to forecast the probability of these securities achieving higher performances than the broad market. To help achieve the desired result, a Monte Carlo simulation was created, to build a thirty-year projection, being the inputs the geometric mean and the standard deviation, and the output is the median value of the simulations performed, which is compared to a benchmark median, through a percentage value. Similar work was performed by Dilellio et al. (2014) where a century-old portfolio reallocation using stocks, bonds, and inverse or leverage funds as asset classes to determine the final portfolio value using a Monte Carlo simulation.

Furthermore, to help achieve the desired results, there are also two secondary objectives, that we intend to answer by the model used. The first one concerns what past performances were on the ETFs considered, which includes the drawdowns of the European Sovereign Debt Crisis and Coronavirus Pandemic. Also, the other secondary objective is to disclose the returns on the investment of the funds chosen, by stating the final value of the portfolio.

Having this as the base case problem of the study, this document was structured with chapters and subsequently subchapters.

The literature review is chapter one in which key definitions regarding ETFs, ESG, clean energy investment, the role of governments and corporations to tackle the rise in global temperatures, and some keywords are presented, concerning clean energy.

Following this chapter, there is the Methodology of Investigation which is dedicated to creating a set of rules to choose the clean energy ETFs as well as the period of study, followed by the method of research used - a Monte Carlo Simulation with Geometric Brownian Motion attached.

The third chapter is dedicated to the explanation of the elaboration of this model in multiple Excel spreadsheets in a way all the information is interconnected. In it, the past performance of the funds is evaluated to create future predictions using multiple simulations.

The fourth chapter concerns the evaluation of results obtained from the different simulations and also it is compared the probability of the clean energy ETFs achieving higher returns than a broad market fund.

The final chapter connects all of the work written in this thesis where are established some conclusions about the model presented, some limitations on the elaboration of this model, and future avenues to be addressed for future research.

Chapter 1 - Literature review

“The stock market is a device to transfer money from the impatient to the patient.” - *Warren Buffett*

There are three important concepts when analyzing this chapter. The first one concerns the Exchange-Traded Funds and how they have become one of the most popular assets in the last couple of decades and it is described how that was achieved. Secondly, a growing concern that the general population hold is to create a positive impact through environmental, social, and governance practices, which is explained in detail in the second part of this chapter. The last subsection is the integration of the two previous concepts where there is a focus on the different types of renewable energy sources.

1. Exchange-Traded Funds

In this section, it is presented a suitable definition of an ETF, as well as their history, and also, is clarified the differences between them and investment funds since they can be similar to those who are not familiar with these expressions. Furthermore, we look at the different types of ETFs and how they are created on both primary and secondary markets. It is then explained the intrinsic risk that holders of this security have to take into consideration when buying this asset.

1.1. What an ETF is

The literature about ETFs is substantially rich regarding this subject, along with reports and data analysis. ETF.com and a subpage of Financial Times have the latest news about ETFs. TrackInsight and justETF have a huge database on this topic as well as the analytics the investors need. Also, people can learn more about it through media content on Bloomberg's weekly rubric “Bloomberg ETF IQ” and also listen to some podcasts such as “Let´s Talk ETFs” or “ETF Prime”.

The definition provided by Vanguard (2016) about ETFs is that they are similar to a traditional investment fund, although they are based on an index, which can be traded on a stock exchange, through stockbrokers or stockbrokers' platforms. They offer diversification through what the ETF holds in the outspread of the market, instead of the concentration of risk in a few holdings, meaning they are another approach to access the market through a broad index.

In addition, the U.S. Securities and Exchange Commission [3] (SEC) explains that an ETF is included in the group of exchange-traded products (ETP [4]) which have been standardized as open-end funds. Investors can buy shares of ETFs as well as trade them as an active or hedging strategy. Since some of the costs are absent in these funds or they are held by the ETF issuer, a lot of them have lower operating expenses than mutual or investment funds (Securities and Exchange Commission, 2019).

Moreover, a report provided by the Investment Company Institute (2021) completes adding that an ETF offers shares in a league of stocks, bonds, as well as other assets. The majority are regulated by the SEC and enrolled in the Investment Company Act of 1940, meaning they are submitted to the same requirements despite their asset class. In regards to securities, the shares along with the shareholders are shielded in the event of a default by an Authorized Participant (AP[5]).

Furthermore, Pinheiro and Varela (2018) suggest that ETFs can provide competitiveness to the market since it is a way to diversify a portfolio and bring additional liquidity with low cost structure and available to retail investors.

1.2. History of these funds

The history of ETFs is closely tied to the creation of mutual funds. Historians consider that this concept is as old as a country. It is believed that was created in the Netherlands amid the American Revolutionary War, from 1775 to 1783. The connection between a

[3] The appropriate entity that regulates the United States' financial markets.
[4] Other types of ETP are the exchange-traded commodities and the exchange-traded notes. The definition definition will be provided ahead.
[5] This term refers to large institutions which act as authorized trading participants on stock exchanges. They have an agreement to allow them to create and redeem ETF shares directly with the issuer.

mutual fund and this war has nothing in common but financing by a mutual fund overseas (Catherwood, 2019). Nowadays, it is not very different from a closed-end fund that invests in an emerging economy or developed one, believing that will thrive in the future.

More than one century and a half later, in 1924, the Massachusetts Investors Trust created the first open-end fund that accepted the continuous issue and redemption of shares, which is closely tied to the net asset value (NAV) and allowed a fair price per share owned. Moreover, the NAV price of this fund was cited in the journals meaning it was a way of promoting the fund as well as updating the investors on the fund's price.

Having the Roaring Twenties as the center stage, many banks were the key "players" of open and closed-end funds. They would lend depositors up to one hundred percent to buy the shares. This uncontrolled unchecked liberal practice would later start a downwards financial spiral that culminated in the crisis of 1929, wiping out small investors, banks, and the whole financial market.

After decades of turmoil in the markets due to the financial crisis and war, new issuers arrived in the 1960s, for instance, Merrill Lynch created hundreds of funds with billions in asset inflows (Ferri, 2011).

In 1975, Vanguard launched the first index-based fund that tracked the S&P 500. With the progress in electronic equipment one and a half-decade later, algorithmic trading would influence future generations as well as the ability to intraday trading by investors, and, in 1995, Nathan Most and Steven Bloom developed the Standard & Poor's Depositary Receipts (SPDR). The official name is SPDR Trust Series 1, although they are commonly known as SPY ETF. It has later grown into the largest ETF in the world with 336 billion USD as of March 2021 (YCharts, 2021). Soon other participants created ETFs that closely mirror the performance of the major indexes such as the Diamonds ETF for the Dow Jones Industrial Average and the PowerShares QQQ that follows the NASDAQ-100 (Giraud et al., 2020).

Table 1 Top 10 ETFs by Assets Under Management (AUM)

Symbol	Name of the ETF	Assets Under Management	Average Daily Share Volume (3 months)
SPY	SPDR S&P 500 ETF	$342,846,000.00	80,349,375
IVV	iShares Core S&P 500 ETF	$256,599,000.00	4,252,986
VTI	Vanguard Total Stock Market ETF	$219,737,000.00	4,433,373
VOO	Vanguard S&P 500 ETF	$203,322,000.00	3,915,083
QQQ	Invesco (PowerShares) QQQ	$151,444,000.00	47,989,508
VEA	Vanguard FTSE Developed Markets ETF	$92,782,100.00	9,720,773
IEFA	iShares Core MSCI EAFE ETF	$86,443,200.00	9,106,955
AGG	iShares Core U.S. Aggregate Bond ETF	$84,465,400.00	6,300,333
IEMG	iShares Core MSCI Emerging Markets ETF	$76,267,200.00	13,335,376
VWO	Vanguard FTSE Emerging Markets ETF	$75,584,900.00	11,467,735

Note 1: The term AUM refers to the total market value that is managed by any financial institution on behalf of its clients.

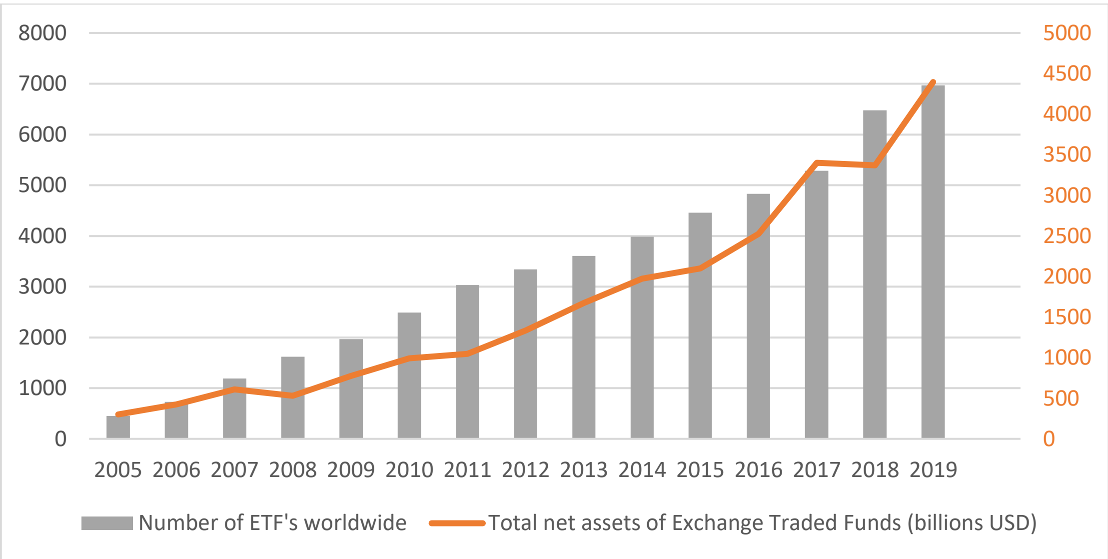
Note 2: The average daily volume indicates the average number of traded shares, based on the last three months, as of April 2021.

Source: ETFDatabase (2021b)

New advances in the structure of the ETF structure made Morgan Stanley alongside Barclays Global Investors to create the World Equity Benchmark Shares (WEBS) on the American Stock Exchange in 1996. In essence, the main difference to the SPDR is that they were considered the first-ever mutual fund and, under the Company Act of 1940 – a law fixed by the SEC, they were flexible to customize their holdings rather than replicate the index one hundred percent (Haslem, 2003).

Many new products were being developed in the twentieth century. Some honorable mentions are the Vanguard Index Participation Equity Receipts (VIPERs) from Vanguard which linked together the concept of ETF and open-end fund; also the creation of commodity ETFs due to the skyrocket in oil prices and precious metals and, since this work is about clean energy, one of the first ETFs in this sector was the Invesco WilderHill Clean Energy ETF (still on the market) that was created in March 2005. It is evident the AUM that the top 10 ETFs have nowadays, present in Table 1 and their growth from 2005 to 2019 is noticeable in Chart 1.

Chart 1 Evolution of ETFs' number and AUM



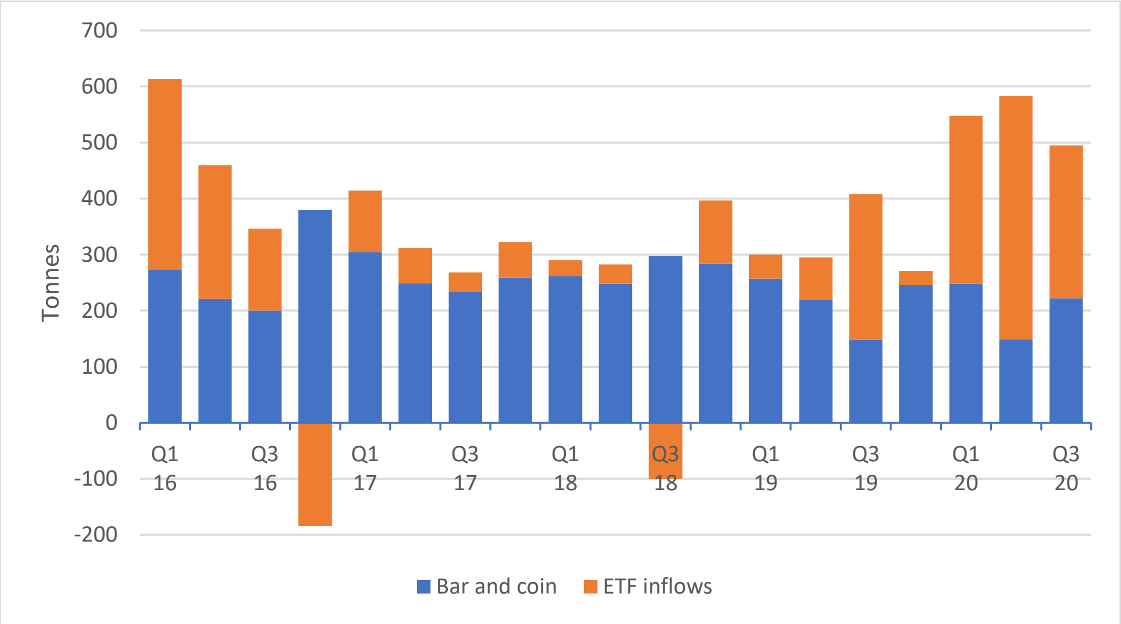
Source: Norrestad (2021)

1.3. Other types of ETFs besides equity

The previous funds mentioned are derived from companies traded in the stock market, therefore making them equity ETFs. This topic references other types that invest in other asset classes such as commodities or bonds.

Exchange-Traded Commodities are one of the favorites by investors to reduce the overall variance of the portfolio. They are comprised of a single commodity such as gold, silver, or other commodities such as agricultural goods or natural resources, although investors have a higher tendency to pick precious metals. According to Mukul et al. (2012), gold investment has a negative correlation with equity investment. It can act as a perfect instrument for hedging equity investment risk because of its low volatility. A combination of gold ETFs as well as equity is expected to reduce the overall risk of the portfolio. In times of uncertainty, it is a good choice for investors. It can be validated by a report from World Gold Council (2020), stating that global gold ETF holdings have been increasing, as shown in Chart 2, because of their uniqueness such as cost-effectiveness, efficiency in tracking the gold spot price, and the fact that they are backed by physical gold (Kosev & Williams, 2011).

Chart 2 Inflows in gold ETFs as primary investment demand for gold in 2020



Note: As of 30 September 2020.

Source: World Gold Council (2020)

Although **Leveraged and Inverse ETFs** can provide excellent or terrible opportunities because they invest in derivatives such as futures or swaps, they should be held for no more than one day (Cheng & Madhavan, 2010; Little, 2010). Trainor (2017) further suggests that leveraged ETFs can be profitable in the long-term and even optimal only for those who are extremely confident, clairvoyant, or during low-volatility markets. These products can provide exposure to the underlying asset without the need to invest the full amount the asset is traded.

Bond ETFs remodel the bond market into an efficient and organized one, seeking to deliver investment opportunities at a low cost, the ability to trade the desired volume and being a crucial instrument in the fixed-income market (iShares, 2021). Nonetheless, the liquidity discrepancy, driven by intermediary costs, is evident in these types of investments and reveals critical to the evolution of bond ETFs and ETFs in general. This represents an important issue APs should take into account in the future (Pan & Zeng, 2019).

Usually, ETFs are tied to the underlying benchmark that they track, as sharply as possible. In **Actively Managed ETFs** portfolio managers invest in assets that are likely to outperform the market. Kremnitzer (2012) concludes that indeed the relationship between actively managed is in line with the superior risk and expense ratios relative to passive management in emerging markets. When in these markets, where the information is less perfect and active managers can attain privileged information, extraordinary returns can be achieved. One of the most popular funds among investors is the ARKK ETF, a fund managed by Catherine D. Wood with AUM of $17.7 Billion (Ark Invest, 2021).

Almost 10 years ago a programmer named Laszlo Hanyecz made a post on a Bitcoin forum, that he intended to buy a couple of pizzas for 10.000 Bitcoins (BTC). At the time, this amount of BTC was worth 41 USD. Fast forward to today and the price of BTC is trading in the range of $55.000 to $59.000 as of May 2021, some companies are carrying a part of their balance sheet in BTC - MicroStrategy and Tesla - and, new products are being developed to meet consumer needs. One of these is the **Bitcoin ETF** which invests directly in BTC or other cryptocurrencies and could solidify crypto-related securities as an investment asset. As of May 10, 2021, Purpose Investments (in Canada) have two

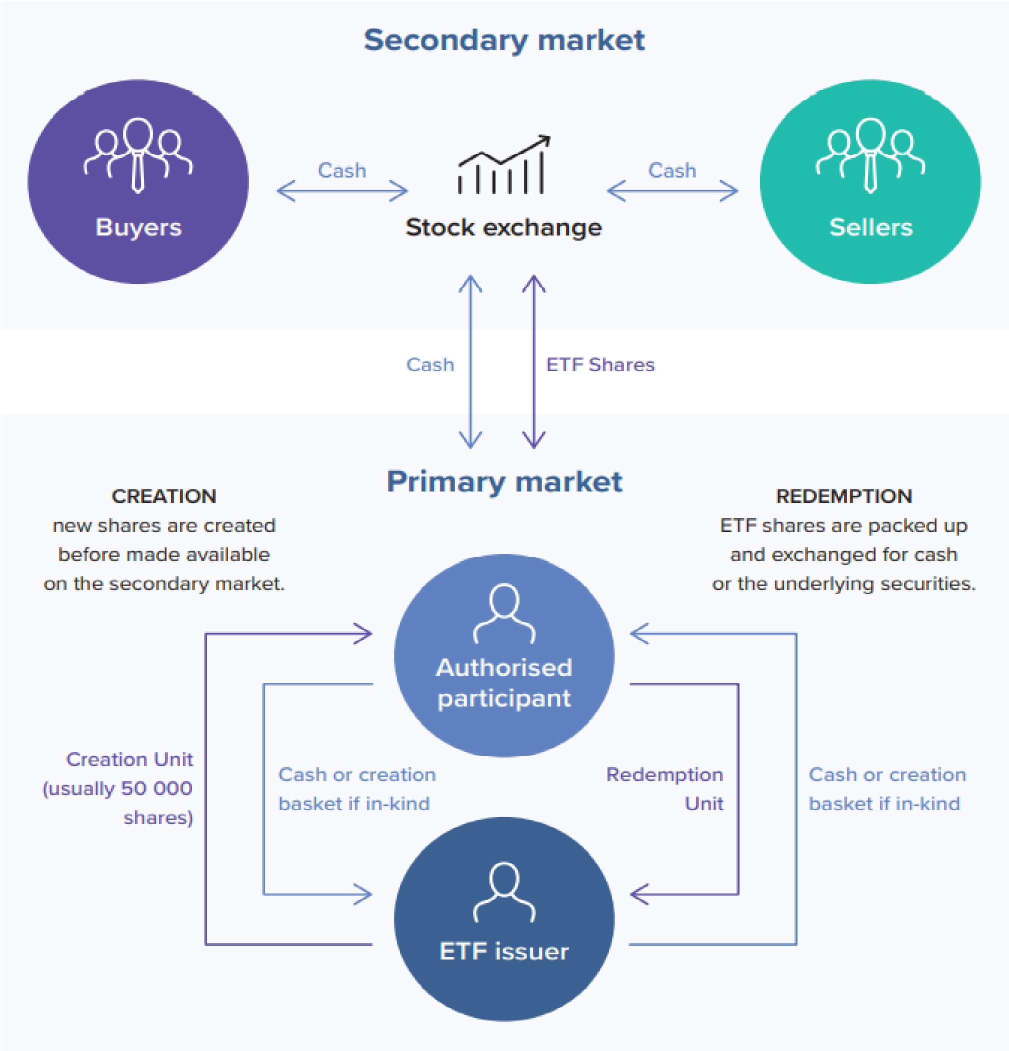
ETFs with Bitcoin and Ethereum as their backbone. In the United States, there have been several attempts to create one, but the SEC rejected stating that the main reasons were the volatility in the crypto market, BTC being unregulated and frequent market manipulation (Binance Academy, 2021). So, this type of investment would be a good asset for a tax-free retirement account and could lead to more institutional investors adopting cryptocurrencies (PurposeInvestments, 2021).

Although the definitions provided are based on the broader asset types of ETFs, there are also other designations for the types of ETFs we can invest in. For instance, they can be categorized by theme, segment, sector, or geography.

1.4. Creation and redemption

To understand how an ETF works we must follow the in-kind creation and redemption's shares process. This system is what makes them less expensive, more transparent and more tax-efficient than the traditional mutual funds' counterparts (Gastineau, 2004). This is synthesized in Figure 2, where big blocks of shares, of at least 50.000 shares, are created and redeemed in the primary market while the ETF shares are traded in the secondary market, in smaller quantities (Peyper, 2014).

Figure 2 Primary and secondary market's symbiosis on ETFs



Source: Giraud et al. (2020)

The process of creation and redemption of ETFs has three main parties that include **ETF issuers**, **Authorized Participants** and **Stock Exchanges**.

Since ETFs track the underlying performance of an index as strictly as possible, the ETF issuer needs a license from Index Publishers in order to operate an ETF (Groves, 2011). Although this is the common way for ETF issuers, some, to avoid the licensing fees, can create their own index, nevertheless, they would also have to handle the cost of having an outsider fund manager supervise the performance of the ETF (Maeda, 2008).

Table 2 Top 10 ETF issuers, as of April 26, 2021

ETF issuer	Assets Under Management ($MM)	Fund Flow ($MM)	Number of ETFs
iShares	2,218,209.28	73,313.12	375
Vanguard	1,737,895.59	115,582.12	82
State Street SPDR	942,306.72	13,051.95	141
Invesco	336,544.51	16,623.07	228
Charles Schwab	231,457.61	11,936.69	25
First Trust	126,538.52	6,040.16	177
VanEck	58,826.75	2,963.54	58
J.P. Morgan	58,360.24	-1,642.19	34
ProShares	54,468.56	2,642.12	131
ARK Invest	49,138.35	10,323.45	8

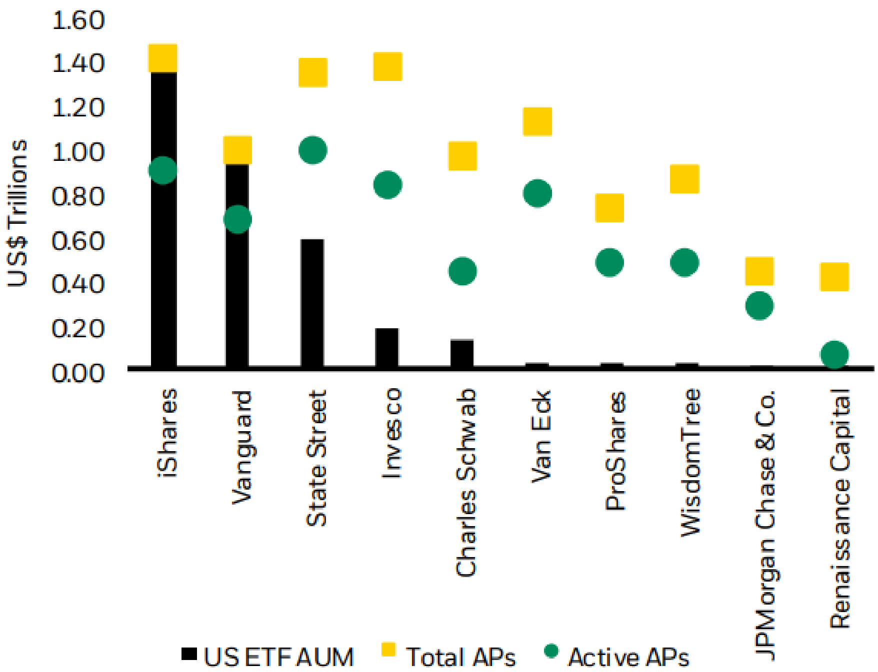
Note: Fund flows are based on their aggregate last three months.

Source: ETF Database (2021a)

The Authorized Participants are often market makers and can be large financial institutions (i.e. banks) or brokers/dealers that interact with the ETF issuer to create or redeem shares. This mechanism adjusts the number of existing shares and keeps the secondary market ETF's price as close as the value of their underlying securities. Each AP has an agreement with the ETF issuer giving them the right (not obligation) to create and redeem ETF shares (BlackRock, 2020).

When ETF shares have a higher demand than supply in the secondary market, the APs and ETF issuers work together to create more shares, through a "creation basket" coupled with cash, that creates the net asset value. The ETF issuer instead, delivers new shares to the AP and can sell them in the secondary market. Otherwise, if the supply exceeds demand, the AP must sell the existing shares they own, either from inventory or they can buy from the secondary market, and deliver them to the ETF issuer. In return, the ETF issuer gives the AP a "redemption basket" with cash (BlackRock, 2020). Generally, the higher the AUM an ETF provider has, the more APs he also has, as demonstrated in Figure 3.

Figure 3 Number of APs by ETF issuer, as of March 27, 2020



Note: report ending periods from January 1, 2019 to December 31, 2019.

Source: Bloomberg and BlackRock (2020)

Retail investors can also participate, through a secondary market, meaning that they do not trade the fund directly rather, they exchange shares between themselves or with APs or brokers. These last can provide liquidity for investors to operate and thus reduce, by a significant amount, the transaction costs - because investors do not trade the underlying securities. Usually, the secondary market's volume is four times greater than the primary market, according to statistics provided by Antoniewicz and Heinrichs (2014).

Through these combined market participants, we can calculate the fair value of the ETF which is the Net Asset Value. Third parties can determine, as well, the fair Intraday Indicative Value, or iNAV, every fifteen seconds, based on the most recent trade (Lettau & Madhavan, 2018). This formula is adjusted at least once daily and can be described as (Securities and Exchange Commission, n.d.):

$$Net\ Asset\ Value\ (NAV) = \frac{(total\ value\ of\ assets - total\ value\ of\ liabilities)}{outstanding\ shares} \quad (1)$$

Since the ETF market price is not always in sync with the NAV, because of market inefficiencies, - i.e., markets for underlying securities are closed because of time zones or accounting standards in different countries - there can arise some discrepancies between the prices traded in the primary and secondary market, thus creating arbitrage opportunities if the price gap between these markets becomes ample.

When an ETF price is trading at a discount price than the AP's estimated value (ETF price is below NAV) the AP can choose to buy shares in return for the ETF's underlying securities, which can be sold for a profit. Conversely, when the price of the ETF is above its NAV, the ETF is being traded at a premium and the AP can buy shares in the secondary market and deliver them to the ETF issuer at NAV price and thus raising the market price to a closer NAV price. This constitutes the basis of the ETF arbitrage (Securities and Exchange Commission, 2004).

Madhavan and Sobczyk (2016) created a model that tries to explain how premiums and discounts do not necessarily mean mispricing or an arbitrage opportunity and how ETF returns can be more volatile than the underlying benchmark. The study includes 947 US-domiciled equity and fixed income ETF and concluded that the price discovery differs considerably across funds and is related to their liquidity. During periods of financial markets' stress, for instance, the 2008 financial crisis, the speed of price discovery is shorter for US-listed equity funds and greater for international fixed-income funds, meaning that ETFs are not the origin of additional volatility or systemic risk.

This represents a more efficient way to operate than open-ended mutual funds, where liquidity is set once at the end of each day and exclusively through the NAV. In that scope, exchange-traded funds can have the price determined by the congregation of buyers and sellers on the secondary market.

1.5. Systematic risk of ETFs

The foundation of modern finance is established on basis of the modern portfolio theory, binding together the choice of a suitable portfolio and market equilibrium. This theory states that a risk of a security's price is composed of an (A) idiosyncratic factor that is a risk specific to a certain asset and the variance can be reduced through diversification and

(B) systematic risk which extends to the whole market and even diversification cannot eradicate it (Bodie et al., 2008; Markowitz, 1952).

Although an ETF is a good way to diversify any portfolio and be less exposed to market volatility because they carry more than one asset and since they are financial products, they are not immune to loss of capital, and we will explore some of the systematic risks that they bear.

1.5.1. Issuer concentration

In Europe, the top three ETF providers are concentrated on a small market niche integrated by BlackRock with 44.3% of the market share, followed by Xtrackers with 11% and Lyxor dominating 7.3% of the European market. In the United States, the landscape is not very different with BlackRock with a market dominance of 35.7% followed by Vanguard and State Street (Eckett, 2021; ETF Database, 2021a), as stated in Appendix 1. This poses questions about the market concentration where BlackRock dominates the United States and European markets with a huge gap to the following competitors, showing that few investment companies make decisions that could if they wish to, move the entire market in their favor.

These large organizations benefit from economies of scale meaning they can increase their gains whilst keeping costs relatively low. This becomes a huge benefit since they can reduce the expense ratio and are able to have new technology reducing, even more, the costs in the long term. Understandably this becomes an entry barrier to new issuers or those with lower assets under management (Walker, 2018).

A common strategy that hedge funds execute is called "pair trading" and takes place when taken a long position in one stock and a short position on a complementary one. This happens when correlated stock prices diverge from their normal performance and occur in ETFs and certain paired currencies (Deshpande & Barmish, 2016). In the specific case of an ETF, it is not uncommon to have a divergence between its price and the underlying benchmark's price, called tracking error and it is negatively correlated with the amount of liquidity or AUM a fund has (Tsalikis & Papadopoulos, 2019). That is why hedge funds apply the "buy the stock, short the industry" strategy, having sometimes, short interest greater than 100 percent, as shown in Figure 4.

Figure 4 Most short interest securities as of Feb 5, 2021

Name	Short interest	Market value
SPDR S&P Retail ETF	188.4%	$0.5 billion
SPDR S&P BIOTECH ETF	97.6%	$8.6 billion
SPDR S&P Oil & Gas Exploration & Production ETF	95.7%	$2.7 billion
GameStop	88.6%	$3.7 billion

Note: Data from January 27, 2021.

Source: Ho (2021)

Also, the closure of a fund is something that investors should be aware of, or in extreme situations the default of an issuer. Fund closure is frequent and about 50 to 80 of them are terminated annually. In the event of this occurrence, the price should converge to the NAV, and investors are expected to receive settlement in cash should not be reddemed after delisting notice period (Madhavan, 2016).

Another issue can arise when funds have derivative positions in their portfolio such as exchange-traded notes and synthetic ETFs that use swap positions. Unlike ETFs that have collateral, these are unsecured debt obligations, and the risk lies in the counterpart might fail to fulfill his part in a swap contract. Sometimes the credit risk in the securities mentioned is meaningful and is incoherent with market prices (Cserna et al., 2013).

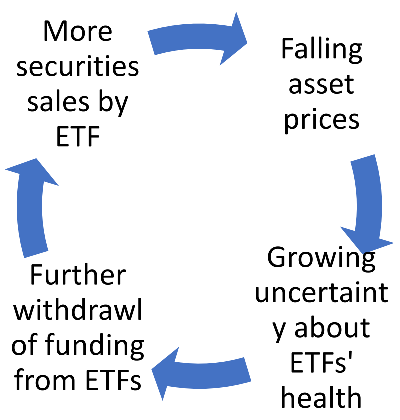
1.5.2. Liquidity mismatch

Liquidity can be described as how well an investor or market participant can buy or sell securities without largely affecting the price change. The referred correlates liquidity in the underlying securities, liquidity in the primary market, and in the secondary market, being the latter the one that has the highest liquidity amount. This should be true in an efficient market as ETFs are as liquid as their underlying securities, but questions can arise in periods of market stress.

During this period there could be a financial contagion or the spread of irregularities and negativeness from one market to another (Dornbusch et al., 2000; Pritsker, 2001). It occurs when a shareholder wants to get rid of a security but instead, must sell others because the market has become less liquid, making more liquidity pressure on the financial market, especially on markets where ETFs are made of less liquid securities – for instance, in emerging markets (IMF, 2018; Yavas & Rezayat, 2016).

Also, a fund's response to asset redemption is selling securities and, in a stress scenario could create more redemption pressure in an ETF, resulting in a negative feedback loop in terms of liquidity and volatility of the fund's holdings, as presented in Figure 5 (Coval & Stafford, 2007). To complement this definition, Shleifer et al. (2011) state that a "fire sale is essentially a forced sale of an asset at a dislocated price" meaning that market participants become indebted and cannot acquire more assets, so they start selling their worst-performing assets.

Figure 5 Feedback loop between security prices, financial market, and ETFs' health



Source: adapted from Baranova et al. (2017)

Furthermore, in these crisis periods Authorized Participants may decide not to engage in an active trading strategy and simply "step away" from trading in the primary market, and the arbitrage that they provide becomes more unreliable as higher the volatility gets (Nagel, 2012; Pan & Zeng, 2019). If it happens, another AP steps in to provide liquidity because, on average, the largest ETFs have about 38 APs (Antoniewicz & Heinrichs, 2015). In the extremely unlikely event that all of them cease their trading, the fund would operate as a closed-end fund, with a limited number of shares.

2. ESG

In this section, there is an explanation of the Environmental, Social and Governance factors, that are becoming more publicized and implemented by communities, as well as some examples of the practice or use of these elements.

2.1. Framework

Kofi Annan (2004), the former United Nations Secretary-General addressed the Commission on Human Rights stating that "We must give greater attention to environmental problems and tensions related to competition over natural resources" and "work together with the international financial institutions, (…) to ensure that young people get the chance to better themselves through education and peaceful employment". So, two years later, alongside large financial institutions, the Unoted Nations launched Principles for Responsible Investing (PRI) believing that since financial decisions feed the economy's growth and it is not reflected in some major fields like environmental practices, responsible conduct in social issues, and governance challenges, should be addressed, being the main objective, the long-term improvement returns and creation of sustainable markets (United Nations, 2006).

One way to define some key metrics of ESG investing is through established ESG raters, evident in Figure 6. This aids in further enhancing the future of sustainable investing so that more funds can adopt well-defined strategies for their portfolios and a lot of index providers and rating agencies helped develop this trend. Some methodologies vary from one rater to another but although different, they serve the same purpose which is to help investors to identify companies with sustainable practices. Some provide data on the market such as Bloomberg and Thomson Reuters and others study financial diligence like MSCI (Boffo & Patalano, 2020).

Figure 6 ESG factors according to major raters

Pillar	Thomson Reuters	MSCI	Bloomberg
Environmental	Resource Use	Climate Change	Carbon Emissions
	Emissions	Natural resources	Climate change effects
	Innovation	Pollution & waste	Pollution
		Environmental opportunities	Waste disposal
			Renewable energy
			Resource depletion
Social	Workforce	Human capital	Supply chain
	Human Rights	Product liability	Discrimination
	Community	Stakeholder opposition	Political contributions
	Product Responsibility	Social opportunities	Diversity
			Human rights
			Community relations
Governance	Management	Corporate governance	Cumulative voting
	Shareholders	Corporate behaviour	Executive compensation
	CSR strategy		Shareholders' rights
			Takeover defence
			Staggered boards
			Independent directors
Key metrics and submetrics	186	34	>120

Source: Boffo and Patalano (2020)

Since the literature is extensive in what regards ESG, only some key topics will be addressed with a special focus on the environmental area, since it can blend with clean energy, which will be presented further ahead.

2.2. Environment

We can integrate some concepts into this topic and one that matters is the corporate environmental responsibility (CER) that more companies are associating in their mission. It came in response to the environment's misbehavior accusations that some firms were practicing unethical methods for short-term profits (Gunningham, 2009). Another metric that is important in this field and moderately correlated to CER is the corporate environmental performance and this metric is negatively correlated to market risk (Horváthová, 2010; Muhammad et al., 2015).

(Flammer, 2015) states that shareholders take positive actions when a company announces environmentally friendly actions and they react poorly when presented with eco-harmful conduct. Furthermore, if a company takes environmental practices a good environmental engagement as a standard, it is highly punished for harmful ecologic practices and not so rewarding if the firm takes further green initiatives (Flammer, 2013).

In the supply chain, Banerjee et al. (2014) explore the relationship between a customer and a supplier if the last do environmentally bad practices and conclude that the vendor is less likely to be chosen by their clients. Moreover, when a customer is environmentally conscious their relationship is even more negative, because of additional concerns that suppliers might take even more negative disruptions on nature.

Another strand of research about the environmental profile of a company and the effect on the cost of capital concludes that investors take into consideration firms' concerns about the environment, generating more equity and debt cost to the corporation. Additionally, since the cost of equity relates to the expected return on investment, and the cost of debt is calculated according to the bank loans, these costs are higher for companies that care about green policies and are lower for those with ecological strengths (Chava, 2014).

Krueger et al. (2020) add that a portion of institutional investors expect global warming far more significant and as a result could affect the performance of their portfolio. Also, it is believed that they invest in climate securities to protect their reputation and to provide returns on investment. And, although the overall industry is in its initial stages, investors are more willing to accept a low-carbon industry in the economy.

In regard to public disclosure, Ilhan et al. (2021) determine that efforts were being made over the years, but still in formation about climate should be mandatory, carefully detailed, and standard. So, to standardize information, a few authors developed indicators to determine environmental risk and carbon footprint.

Georgopoulou et al. (2015) propose a methodologic framework and a tool called "CLIMA-RISK" that quantifies different monetary metrics related to banks, from risk exposure corresponding to climate change in Greek banks.

Barnett et al. (2020) created a structural model based on decisions under uncertainty from climate and economy. Climate uncertainty involves human activity on the environment and economic uncertainty concerns the influence of climate harm on the well-being of the population.

Görgen et al. (2020) conceived the “Brown-Green-Score” that is based on different variables such as the total emission that a company produces and its supply chain, - value chain- how carbon policy and emissions are perceived by shareholders and partners (public perception) and strategies that a firm can implement to stay in alignment with the price of carbon, laws and emission reduction - adaptability.

2.3. Social

In the context of increasing concerns about the social responsibilities of companies while they can be profitable and follow a more conscious way of operating, McWilliams et al. (2006) define corporate social responsibility (CSR) as an engagement by the company outside of the compliance area that is not mandatory by law, but still, the company decides to promote social good performance within and outside the company – internal and external stakeholders.

Mohr et al. (2001) add that consumers do not use CSR metrics when they want to buy products/services from the company, but most of the time, they are interested in what the corporation does in this field because they feel like it is important. Furthermore, they often rationalize about what they buy and could contribute to a better society, meaning they value more or fewer companies according to their socially responsible engagement.

Research conducted by Bhattacharya et al. (2004) reports that consumer segments react differently to CSR initiatives, the stakeholders of implementing CRS actions are beneficial not only for the company but to all players that have a relationship with the firm and CSR initiatives are well-perceived from an internal standpoint (awareness and attitudes) than an external one (loyalty).

On the financial side, Roman et al. (1999) try to correlate corporate social performance and corporate financial performance. They analyze past articles from 1970 to 1990 and out of a universe of fifty-one, sixty percent have a positive correlation, five studies have a negative relationship and almost a third do not correlate.

There are a lot of ways a corporation may leverage its CRS. One of them is to promote charitable campaigns to improve the social well-being outside the company, and, also philanthropy to boost the firm’s financial landscape (Porter & Kramer, 2002).

2.4. Governance

The term “governance” applied to a corporation refers to how well the management team is supervised and takes into account the rights of all parties who have a relationship with the company, the stakeholders. Also, other objectives include responsible conduct and the ultimate ambition is to achieve the highest level of efficiency and profitability (du Plessis et al., 2018).

A paper provided by Rao and Tilt (2016), explains that board composition and board diversity constitute a major aspect in creating new viewpoints in an impactful long-term decision of the company. One of the goals that they suggest regarding governance is that literature should further analyze how the development of decision-making applied to ESG decisions are made.

John and Senbet (1998) describe that the most critical aspects of corporate governance are the number of directors, the Chief Executive Officer (CEO) turnover, the dissociation between CEO functions and Chairman functions and the stake, in shares, that the members of the board hold. Also, if a board has a large number of members, – reflecting a large institution – top administration may face difficulties in establishing overall consensus, between all members.

Furthermore, Freeman and McVea (2001) complement the “stakeholder theory” which states that if stakeholders restrict some company’s activities, is up to the management team to comprehend their needs in achieving the best results for the corporation. Nevertheless, what the board usually does is amplify the interest of a particular group: the shareholders. Therefore, the most prosperous action that they should take is to maximize the interest of all stakeholders and not a particular group.

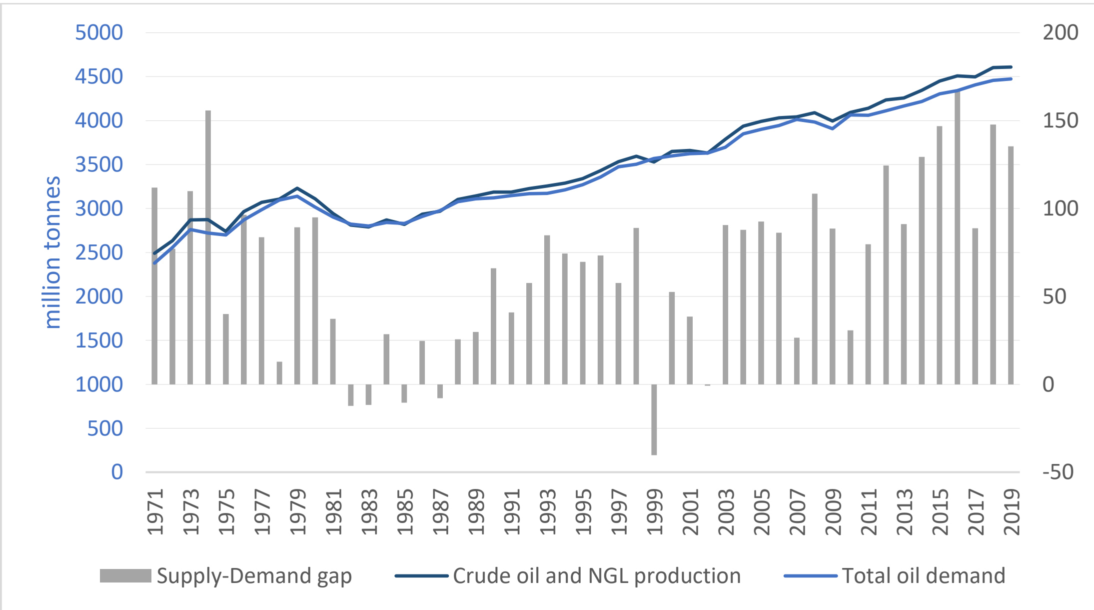
3. Clean energy investing

To introduce this topic it is presented the different types of clean energy sources, explained key concepts like carbon-neutrality and net-zero emissions, and enhances the work that government states are doing to boost clean renewable energy.

3.1.Context

It is important to describe the role that energy has been having since the birth of the industrial revolution. The discovery of fossil fuels, as a way to generate energy, has brought human prosperity over the last 250 years, creating a vicious cycle where more and more is needed to satisfy human needs, as demonstrated in Chart 3. Although this development, they bring problems along, such as the negative impact on the environment, their rarefaction, and the price instability on the market (Pillot et al., 2019).

Chart 3 Global supply and demand of oil from 1971 to 2019



Source: IEA (2021)

The main environmental problems derived from carbon dioxide and greenhouse gas emissions (GHGE) can be almost totally reduced by implementing clean renewable energy sources (RES) (Fornara et al., 2016; Lucas et al., 2018; Mardani et al., 2015; Trop & Goricanec, 2016). To incite this behavior, policy-making decisions must be in line with public opinion (Qazi et al., 2017). Thankfully, social consciousness about this topic is becoming more debated and researched so that present and future generations may not live in a scorching polluted climate.

3.2. Types of renewable energy sources

In a 2014 speech Lagarde addresses "the environmental crisis, which is shaping up to be one of the greatest crises facing our generation and our century. It is also the issue upon which future generations will judge us. If we do nothing, we face a future that is grim indeed" (Lagarde, 2014).

These wise words are in line with a transition to a cleaner, more sustainable way of approaching energy acquisition and expenditure. Not only, in general, populations are worried about what might happen on our planet but the studies on this topic have been increasing (Rizzi et al., 2014).

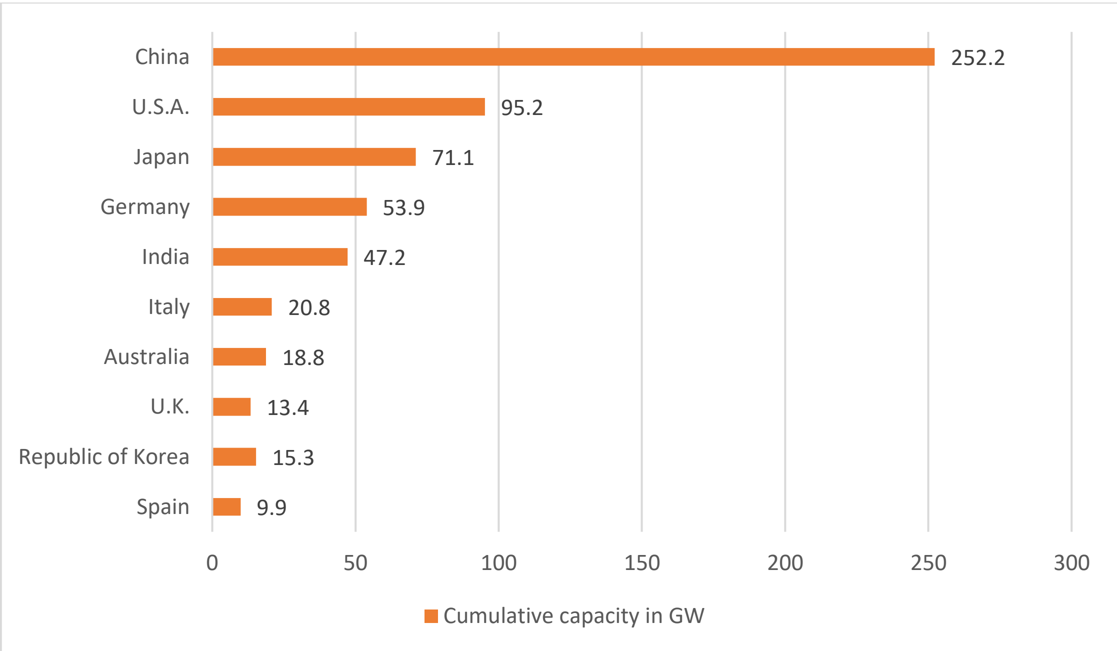
After the breakout of the industrial revolution, people started using fossil sources in their everyday life, such as coal, oil, and natural gas. Nowadays these types of non-renewable energy are being depicted as the root of a negative environmental change, because of the carbon dioxide and greenhouse gases (GHG) and their limited lifespan in nature (Lucas et al., 2018). This is where renewable energy sources, with the most usual ones being solar, wind and water, come into consideration because of the almost zero emissions of these types of gases (Fornara et al., 2016; Trop & Goricanec, 2016).

In this subchapter, we look at the different types of renewable energy sources and what their usabilities are.

3.2.1. Solar energy

This type of energy comes from the sun and solar photovoltaic (PV) structures transform sunlight into electricity (J. Brown & Hendry, 2009; Olszewski et al., 2019). In these systems, the sunlight is absorbed by a panel's cell and creates an electrical field, and then converted into energy. Usually, a single PV cell is small and has little power capacity (1 to 2 volts), and to increase the harvested power, cells can be linked to form modules/ panels (Sahu, 2017). They are then grid-connected where companies and private consumers can produce and sell their overcapacity to the grid, making them prosumers (Michas et al., 2019). The efficiency in producing these panels have been increasing, reducing manufacturing costs and expanding the total market demand (Ornetzeder & Rohracher, 2013). Figure 7 shows the largest markets for solar photovoltaics in 2020 and the huge gap between China and the remaining countries, regarding its capacity in Gigawatts.

Figure 7 Cumulative solar photovoltaic capacity globally by country in 2020



Source: Jaganmohan (2021)

There is also another category for solar energy usage besides photovoltaic which is thermal energy. In this system, solar energy is transformed into thermal energy, meaning that their end usage will be towards solar water heaters, cookers, cooling systems and refrigeration (Abed & Badescu, 2015; Tijani et al., 2018; Xue, 2016).

3.2.2. Wind energy

In the past decades wind energy has been consistently growing, to integrate, electrical power systems all over the world. This development is considered necessary in a time when total energy consumption will not decrease and the climate crisis is on the agenda of many governments (Bokde et al., 2019).

When presented with this type of renewable energy source we think about collective big turbines that generate electricity for an entire community. Although similar, we must distinguish between onshore and offshore turbines since their affordability, cost per kWh, assembly and geographic exposure can change drastically.

The onshore wind turbines, that are built and are stationed inland, have a lower cost per kWh in relation to the offshore ones. Usually, they are pre-constructed, and their shipment is relatively easy and is very common in places like Europe, the USA, and China.

As for the offshore wind farms, they are located in seas and oceans where the wind flow is stronger, thus they can produce higher amounts of energy. They are expensive to create and a very detailed plan to put them together is needed and they dominate the seascapes of the North Sea and the United States (Lynn, 2011).

Although this development has been thriving, comes along with some critics by local communities, regional and national entities because of the visual, ecological, and auditive burden on the landscape (Hirsh & Sovacool, 2013; Karydis, 2013; Wolsink, 2007). What Jami and Walsh (2016) propose is to increase the public involvement in the planning of this infrastructure, meaning the design and the location of the farms can be picked by local communities. This is known as the participation of invited stakeholders (Cuppen, 2018).

3.2.3. Hydropower energy

Hydropower is the biggest source of renewable energy. It converts kinetic into mechanical energy, using the water flow as a propeller to generate electricity. The hydropower electricity output is proportional to the difference between the water levels and the flow rate (Edenhofer et al., 2011). The plants can be distinguished by design and configuration but mainly there are three base models: the reservoirs, the pumped storage and the run of the river.

The reservoirs, as the name suggests, are where a hydropower scheme where water is stored. When there is electricity demand, water passes through a turbine and is created through a generator. They offer flexibility in what regards base loads and peak intensity of demand, and they are used in irrigation, flood control and drainage (World Energy Council, 2016).

For the pumped storage plants the water is stored in a higher reservoir and when electricity is needed the water flows from the upper reservoir to a lower one, passing through a turbine and creating energy through a generator (Mongird et al., 2020).

Run-of-river hydropower is the smallest growing segment among the three because of the low scalability that impacts the environment. (International Energy Agency, 2021a). In this scenario, the production of energy is possible because water comes from a hilltop or highland and is diverted from the main course of the river, making it a reservoir like a powerplant but on a smaller scale.

This source of energy had been established a long time ago and is not a new trend in the alternative energy sources scope. As de-carbonization rises, it is stated that hydropower is an important element to achieve the goal of doubling up the usage of renewable energy sources by 2030 (International Energy Agency, 2016). Despite this trend, communities debate some challenges that arise from this type of energy.

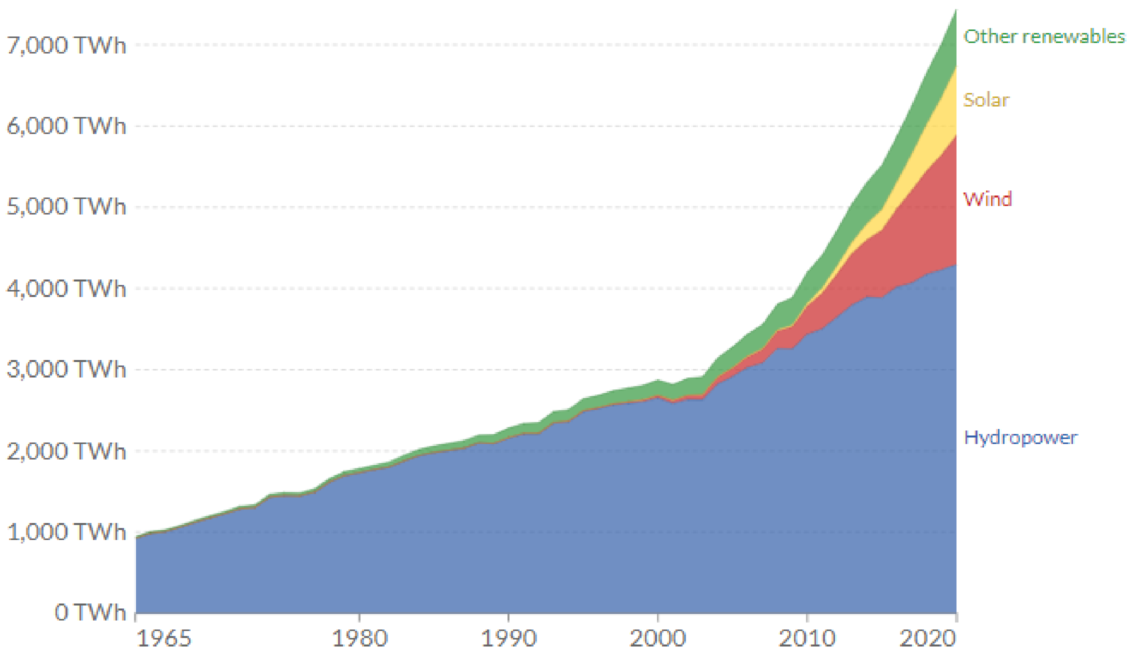
For Elliot, (2016) the electricity generated by these platforms has been in constant growth – specifically for this type is the variable renewable energy – but their integration in systems that seem more disconnected from each other raises some questions related to power stability. Also, since their mechanics are becoming progressively complex, where a hydropower system is comprised of hydraulic, electric, and mechanical subsystems -

control gate, penstock, generator, transformer, powerhouse - their size has been constantly growing, notably in China (Jia, 2016).

3.2.4. Other renewable energy sources

Besides the main renewable energy sources mentioned above, there are others with a lot less expression but are still important in the transition process from petrol to clean energy. They are the geothermal, biomass, wave and tidal energy and represent about 10% of the sustainable energy mix.

Figure 8 Total amount of clean energy produced



Source: BP (2021)

As far as 2020 the share of the three main sources is increasing, widening the gap from the other renewables, although almost doubling their capacity production from 10 years ago - from 381 TWh in 2010 to 700 TWh in 2020, as shown in Figure 8.

Geothermal energy is generated from the heat that is stored in the Earth's crust and is the byproduct of the decay of thousands of years of radioactive particles. For Sui et al. (2019)

this RES has numerous applications besides energy production (high temperature of 150º C), such as industrial application and space heating (low temperatures below 150º C), and has gathered more attention from the communities because of his low environmental impact, regular power output, and the low GHGE. Despite the advantages, it comes with a major burden which is the cost of creating and maintenance of a geothermal well.

There is also biomass which can be attained by increasing organic material such as wood, agriculture residues, and crops. This is the only energy source that can be transformed into power via combustion operation (Tchapda & Pisupati, 2014). The biomass creation process is based on the premise that we can reduce the number of chlorofluorocarbons in the atmosphere by creating more trees and plants, to absorb more carbon than what is released into the air, lowering the greenhouse effect. For the usage of biomass, we need to find manure, discarded lumber, and yard trimmings on local waste streams which are then compressed and dried, to create cork-like units, called pallets, to feed the power units (CNN, 2020). One desired outcome for the future is the improvement of biomass densification, through organic and inorganic materials.

Regarding the oceans, we can capture energy from the movement of the sea, which is commonly known as wave and tidal energy. Although these wave movements are more publicized, we can extract energy from the seas, such as the marine currents, osmotic salinity, and ocean thermal energy conversion (OTEC) (Cascajo et al., 2019). The energy produced from tidal and OTEC appears more often in Asia and Europe, having also this last one more wave energy and salinity gradient power. As far as energy produced from the oceans has a lot of upside potential for the RES generation and new devices are being created, some are underwater and some are floating gadgets, but although these promising technologies there can be some constraints to measure the environmental impact that is yet to be unveiled (Mendoza et al., 2019). Also, the high cost to create these new devices can become an entry barrier to new players, that is why governments should take an active role in promoting this unexplored RES.

3.2.5. Electric Vehicles as a way of clean energy

One of the leading characters, when we talk about global warming, is the transportation sector which is responsible for a third of universal energy demand, and road transportation, in particular, produces 70% of total GHGE to the atmosphere (European Comission, 2021; IRENA, 2017).

To mitigate the rise of global temperatures, to which irreversible damage to the environment – causing extreme weather effects and ice melting – would have taken place, car companies have been transitioning to a more technological and cleaner way of road mobility, such as the electrification of their fleet – electric vehicles (EVs) (Sovacool et al., 2019). Therefore, these companies have come up with new technologies such as Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Fuel Cell Electric Vehicles (FCEVs), and Battery Electric Vehicles (BEVs).

Regarding the HEVs they combine an internal combustion engine and an electric motor as an assistant, to achieve better performance and fuel economy. The PHEVs are somewhat similar to the prior but they also have a plug connection to the electrical grid and have a larger range in electric mode.

As for the FCEVs, they run on natural gas, more specifically, hydrogen that is converted by a fuel cell into electrical energy and discharges only water and heat. Some major constraints involving the FCEVs are the requirements for hydrogen production and the setup costs of a fuel cell (Qin et al., 2014).

BEVs use the electricity provided by battery packs, which are usually comprised of lithium, cobalt, manganese, and nickel - the lithium-ion batteries - that were introduced in the early 1990s and are here to stay mainly because of their extraction costs (National Grid, 2021). These battery packs are a set of single cells that have layers of electrodes, divided by electrolyte and, in this separator is where these metals are most abundant. When there is a discharge in the batteries - EV is moving - the electrolyte pairs negatively charged oxygen with positively charged lithium and these ions travel from an electrode sheet to another; when the reverse process occurs - EV is charging - lithium ions travel from an oxide crystal sheet to a graphite sheet, where they are gathered (Castelvecchi, 2021).

Table 3 Traits of the different EVs

EV Type	BEVs	PHEVs	HEVs	FCEVs
Strength	No emission or very low emission	Lower emission than HEVs	Lower emission than ICE vehicles	No emission or very low emission
	High energy efficiency	High fuel efficiency	High fuel efficiency	High efficiency
	Independent from oil/Low engine noise	Fuel diversity/No range anxiety	No charging station problem	Independent from electricity
Weakness	High purchase and battery cost	Complex technology	Complex technology/Higher cost	High fuel cell cost
	Charging station problems	Management of the energy sources	Management of the energy sources	Technical challenge and cost issue
	Battery replacement requirement	Heavier/Tail-pipe emissions	Dependence on fossil fuel/Tail-pipe emissions/Heavier	Problems of H_2 generation

Source: Dik et al. (2022)

The largest EV market that is responsible for more than 50% of global sales is China and Europe is growing at a pace never seen, with most EVs sold in 2020 (Bibra et al., 2021; IEA, 2021b). Although this growth rate, people still have some concerns when buying these types of vehicles. Range anxiety is the main issue and the current recharging infrastructures are not yet fully matured, making people hesitant when switching to EVs; the car weight is much higher than a combustion engine car due to the battery pack and all of the new technologies associated with it, and the creation of these new electronics may put pressure on the electrical grid in terms of power necessity as well as response time.

3.3. Role of governments/large corporations in promoting and developing clean energy

In order to build the infrastructures linked to clean energy sources, there must an initial investment that could be challenging to private investors. That is why stimulus should be given by governments to support a cleaner way of living that benefits us all, excluding the oil companies.

In this subchapter, it is highlighted some policies being made by governments around the world that try to carry out standard renewable programs.

In the Paris Agreement treaty, some structural goals were defined to limit global warming preferably below 1.5 degrees Celsius. On them, article 6 aims to mitigate GHGE by progressively reducing dependency on coal, supporting EVs as a way of transportation, lowering deforestation, and further investing in renewables (Delbeke et al., 2019).

In the same stance, the United Nations (2015) has proposed a set of goals, the Sustainable Development Goals, relating the green development for all countries. The most relevant targets that are in line with this work are the following:

- Goal 6 is dedicated to clean water and sanitation and the targets proposed are universal access to drinkable water and sanitation for women;
- Goal 7 proposes affordable and clean energy by creating modern energy services, increase the amount of renewable energy that comes from RES, and boosting its efficiency;
- Goal 11 relates to sustainable cities and is achieved by using sustainable and economical transportation systems and supporting ESG practices between national and local policies;
- Goal 13 regards the climate action through implementing environmental standards in governmental policies and improving awareness through education;
- Goal 14 concerns the conservation of oceans and seas through the improvement of the quality of water and water efficiency by reducing deterioration by man-made activities.

To further enhance these strategic conclusions, COP26 was set to fully lay out what governments should do to ensure carbon neutrality by 2050, preserve the ecosystem, finance projects related to sustainable energy, and outline partnerships between governments (United Nations, 2022). In it, the majority of the participants agreed on more aggressive targets to reduce GHGE, but India, which is heavily dependent on coal, argued that wants to phase down this sedimentary rock instead of phasing out, falling short on expectations for the meeting (IETA, 2021).

On a more regional note, the United States are passing a bill called the Build Better Better Act which is the biggest investment made by this country in the matters of renewable energies, and clean technologies. This framework can be described into three major initiatives, namely the clean energy side in which tax credits would be issued to incentivize clean buildings, vehicles, and electricity through the employment of wind, solar, and EV energy. Also, on lowering emissions, the bill intends to cut out stimulus for fossil fuel production and impose new and more strict regulations on offshore oil rigs and the final action intends to further invest in Research and Development (NowThis Earth, 2021; The White House, 2022).

As for the European Union, the plan to cut GHGE is called the Green Deal and the main objective is to achieve carbon neutrality by 2050. The main proposals set to be executed by the 27 members are based on some key steps such as the improvement of air, water, and soil quality by phasing out the production of fossil fuel cars by 2035, imposing a percentage on how much energy should come from renewable sources and planting a sizable quantity of trees across Europe - EU's Common Agricultural Policy (European Commission, 2021). As of January 2022, European lawmakers are still deciding on whether these measures should be approved.

The United Kingdom has managed to reduce its coal dependence from 80% in 1990 to 2% in 2019, mainly due to the self-regulated markets in the energy sector that backed gas investments. Their policy of having net zero emissions by 2050 is in line with European and global action and the ones responsible to oversee the development of renewable energy are the Department for Business, Energy and Industrial Strategy and the Climate Change Committee (MacDonald & Lytton, 2021). In a recent report (Gummer et al., 2020) some key ideas in the transportation, electricity and GHG sectors are presented, to then be integrated into the national agenda. There should be an extensive governmental investment in scaling up BEVs compared to HEVs because the former are expected to be cheaper regarding costs in acquisition and maintenance, as well as upgrading the network related to these vehicles, in engineering more offshore wind farms to meet the expected 140GW production by 2050 and in new policies for GHG removals such as tree planting and increasing the share of energy crop area - low-cost crops intended for energy production and not for agriculture.

On the other side of the globe, we look at some Asian-Pacific countries and what their trend is concerning renewable energy.

To achieve net-zero emissions by 2050, Australia was one of the pioneers in setting renewable energy targets to increase the share of renewable energy production and reduce GHGE. To achieve that the local governments are seeking new contracts with large corporations, mining companies are replacing their energy supply source with a more hybrid one, that links fossil fuels with clean energy, the high interest from foreign companies has sparked a surge in mergers and acquisitions and, the increase of maturity on bond purchase to finance banks (Australian Government, 2021; Li et al., 2020).

Towards the northwest, there is China, the largest producer of electricity worldwide, and the sources of its energy come 57% from coal, 20% from oil, 8% from hydroelectric, and 8% from natural gas (Ritchie & Roser, 2021). In the past few years, China is on track to reduce its GHGE through increased investments in R&D in power storage and in all sources of renewable energy, as well as creating efficient building projects (Runqiu, 2021). Also, President Xi Jinping has lifted restrictions on the energy sector to outside investors, except for nuclear energy, and is reducing incentives to solar and wind power as a result of the decline in their production costs (Wang, 2020).

Finally, in India, the government has created some organizations and programs to accelerate this global clean trend, such as the National Solar Mission to build a more robust framework related to solar and reducing grid costs, the National Policy on Biofuels to create and incentivize the use of biofuel as an alternative to coal or oil, and the National Wind-Solar Hybrid Policy that intends to scale-up solar-wind PV technologies to achieve a more efficient grid infrastructure (Axup et al., 2021; Jethani, 2018).

3.4. Keywords associated with clean energy

When the awareness to change from fossil fuel to green energies, a few years ago, researchers decided to create some key terms to define specific targets or metrics to achieve a more sustainable way of living. The most common is the **net-zero target** to be achieved by most countries due 2050.

This term was first introduced in the 1920s but later develop in the 1970s by Nicholas Georgescu-Roegen, a mathematical economist, formulating that since non-renewable natural resources are finite, there should be more aware of sustainable development (Tool et al., 1981). Later the concept is formulated as a structure where carbon dioxide, GHG, or methane, produced by humans, could be removed by reducing these gases, carbon offsetting, or not emitting gases at all (Oshiro et al., 2018). In theory, to achieve it, the GHG discharged equals the amount of GHG removed, and technologies such as green mobility and renewable energy are paved to reach the desired goal in the mid of century (Masson-Delmotte et al., 2018).

The next step towards decarbonization is the **climate positive** concept. To understand that, the Ministry of Environment of Sweden issued a report in which an effort is proposed to picture a world where more carbon and GHGE are removed than produced (Christiansen & Carton, 2021). In the same thought line, a C40 Cities (2016) report' focuses on waste, energy, and transportation to achieve net negative carbon emissions, proposing further development in high efficient buildings, use of waste to produce other goods and low carbon power sources. Also, another suggestion proposed is the implementation of a credit system in which a credit system is defined regarding tons of carbon reduced or through carbon capture, meaning to achieve a climate positive event, there should be more credits than carbon emissions.

Combining these environmental keywords with finance some need to be addressed such as **green finance**, or green climate that point out any financial tool or investment that promotes not only financial growth but also a positive impact on the environment, therefore financial institutions and governments should be the ones promoting these initiatives - sustainable operations and competent funding (Ante, 2021; Fathihani et al., 2021).

Another key is the definition of what **sustainable finance** means. Migliorelli (2021) argues that the early adoption meant the financial activities that blend high hierarchy decisions and the regard to sustainability, but although primitive this concept is in line with what has been carried forward by this theory. The author additionally proposes that this concept is relevant if can contribute to the advancements in at least one relevant ESG metric.

To promote these environmentally friendly practices, investors may participate in a company's debt through the acquisition of **green bonds**. It is bond-backed security, different from a plain vanilla bond, in a way that the "green" implies projects to promote positive environmental/climate impact (Mok et al., 2020). Research provided by Fatica and Panzica (2021) measures the connection between the issuance of green bonds and the issuer's ecological performance, concluding that non-refinancing companies borrowing these financial instruments exhibit a reduction in carbon intensity, and, they are more evident in those who were and created after Paris Agreement and externally reviewed – although not a standard, governments are pushing to create guidelines and to better define this financial tool - Green Bond Principles.

Moreover, the lack of strict financial regulation can create company or governmental level issues such as **greenwashing**. This term was introduced in the late 1980s and was later coined as disinformation towards practices that are supposed to be sustainable but in reality, differ from the main goal (Grene, 2015). Additionally, a stratagem used to drive demand is to use "green" or sustainable" product labels as a misleading indicator or create marketing campaigns to induce more eco-friendly activities than they are in reality (Migliorelli, 2021).

Chapter 2 - Methodology

"I don't look to jump over seven-foot bars; I look around for one-foot bars that I can step over." - Warren Buffett

This chapter includes four sections. Section 1 refers to how the choice of the sample is done, having in mind the renewable energy types previously mentioned and Section 2 describes the period analyzed in order to extrapolate the future outlook for the different funds.

The next two sections (3 and 4) are dedicated to the methodology used in the study, where Section 3 describes the methodology on Random Walk and a brief overview of how this theory is applied to finance, and more specifically to this work. Also, an introduction to the Geometric Brownian Motion is created since it is the baseline for the model. Section 4 describes the method used to perform the random walk on the portfolio of ETFs chosen and states how this model works since it can be used in areas other than finance.

1. Sample Data

This thesis seeks to compare the performance of some RES categories ETFs, which are a driver of inflows of investment assets, in a near future, to a representative and appropriate benchmark on the equity market.

The selection criteria are based on several factors:

1. The selection of all funds has the equity market as the underlying asset class and its holdings should be comprised of publicly traded companies. The fund should not invest in bonds or be a fund of funds;
2. As an investment strategy, ETFs should not hold any kind of options or derivatives, to profit from market volatility. The only acceptable way to use swaps or forwards is for currency hedging;

3. In this case, the clean energy ETFs will be compared to a representative market fund called "benchmark". The fund will commonly be addressed as such, as a result of being a standard when compared to other funds;
4. The benchmark should be representative of the geography and currency risk where the majority of the funds are located;
5. The clean energy funds, that are the object of study, should be representative of a certain RES category, that was previously mentioned - most notably the ones most representative of the sustainable market share;
6. The ETFs should have a track record of at least five years of consecutive trading.

Based on these key investment criteria, some category filters were created, in which investors should be positioned to encompass the full spectrum of clean investment. The choice of a broad ESG representative must be included as well as some thematic investment, such as a fund that only invests in solar, another in wind, water and lithium.

The choice of a lithium ETF is carefully considered due to the innovative properties and the massive decrease in price in recent years of this mineral in the production of all sorts of technological goods - from smartphones to EVs. Although nickel and cobalt are also used in the production of EVs, lithium is the most abundant and the most logical choice (Goldie-Scot et al., 2021).

Following the research criteria, a search through different databases specialized in ETF trends and analysis was performed. Out of the five specialized websites, thirty-three funds were found regarding the clean energy landscape as demonstrated in Appendix 2.

After that, it is tried to filter these ETFs according to the categories previously established, so the author came up with those most adequate for the investment thesis.

Following the choice of the securities, it is needed to establish the benchmark to compare with the renewable energy funds. Regarding that, it is identified that almost all funds have a geography exposure to the United States of America not exceeding 50 percent of the funds' holdings (except PHO). So, to address all market participants, the most appropriate choice should be a fund that invests in the total addressable market, so a fund that replicates the performance of the *MSCI World Index* must be reliable – and for that reason, MXWO was examined. The fund selection is as follows in Table 4.

It could have also been possible to select another benchmark (for instance an energy ETF such as USO, DBO, or BNO), that in theory, would depict the price of oil at a given moment - spot price. Unfortunately, this is not the case since Oil ETFs are designed to track changes in prices of an individual futures contract, never replicating the spot price (Bessembinder et al., 2012). This means that an investment in this fund invalidates the selection criteria.

2. Sample period

Now, to determine the analysis period in which the ETFs will be studied, it is defined as the end of the Global Financial Crisis of 2008 (Subprime Crisis) and the beginning of the European Sovereign Debt Crisis. There are several reasons why the Financial Crisis is excluded from the sample, namely the massive outflows in all asset classes, the risk of contagion that spread worldwide, and the unbelievable drawdowns (or "maximum pain") investors experienced (Thalassinos et al., 2015).

In light of that, the sample period is defined from 01/01/2010 to 31/12/2021, meaning this period still encompasses a drawdown from the European Sovereign Crisis as well as the Covid Pandemic.

Table 4 ETFs that will be the object of study

Category of the Fund	Ticker	ETF name	Investment thesis of the ETF	Top country exposure	Currency Risk	Inception date
Broad ESG	ICLN	iShares Global Clean Energy ETF	Give investors exposure to companies on solar, wind and other RES, all around the world	U.S.A. (39.69%) Denmark (12.34%)	USD	24/06/2008
Solar	TAN	Invesco Solar ETF	The fund seeks to invest in companies related to the solar energy industry	U.S.A. (48.05%) China (20.28%)	USD	15/04/2008
Wind	FAN	First Trust Global Wind Energy ETF	It invests in public companies that are taking an active stance in the wind energy ecosystem. It imposes some restrictions regarding company's active role in the sector, market capitalization, trading volume and free float	Spain (15.94%) Canada (13.65%)	USD	16/06/2008
Water	PHO	Invesco Water Resources ETF	Tracks the performance of US - listed companies that create products to purify and conserve water	U.S.A. (97.68%) Brazil (1.76%)	USD	06/12/2005
Lithium	LIT	Global X Lithium & Battery Tech ETF	LIT invests in companies that relate to battery cycle (mining, refinement and production)	China (42.62%) U.S.A (21.80%)	USD	22/07/2010
Benchmark	MXWO Index	MSCI World Index	This security seeks to track the performance of big and medium cap companies in developed countries around the world	U.S.A (68.57%) Japan (6.22%)	USD	25/09/2009

Source: Self-elaboration

3. Overview of Random Walk Theory

To understand the Random Walk Theory (RWT) it is critical to explain how analysts can predict how market securities may behave in the short-term. On the one hand, some believe that through the past behavior of the price, history tends to repeat itself, and follow patterns and situations identical in the past – called technical analysis. On the other hand, others evaluate the intrinsic value of an asset and consider what elements should influence the future price. These elements can be external to the company (such as the macroeconomy and industry trends) and internal to the company (through the analysis of earning reports and other financial statements) (Fama, 1965).

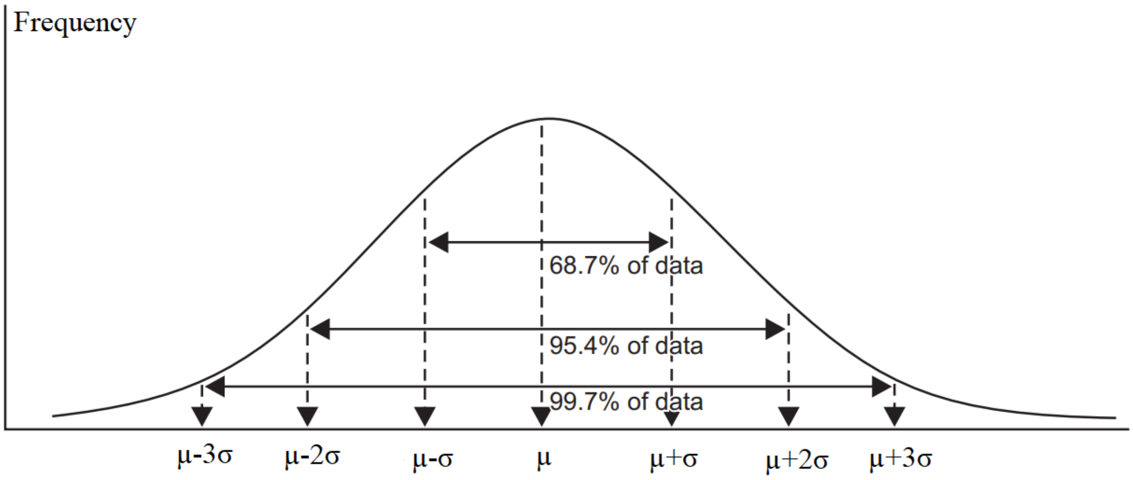
So a valid theory that links these two types of analysis is the chaos theory. It states that price movement in stocks is a byproduct of internal and external factors, and Klioutchnikov et al. (2017) add that this revolutionary path is accompanied by the transition in the use of big data and leverage our understanding of financial markets and its evaluation.

So, through the study of fundamental analysis a shareholder can monitor whether a stock is above or below its fair price, in the long term, and, if the share price represents its fair value, the investor may choose to resort to technical analysis to acquire the security at the best short-term moment possible, using technical indicators (Mishkin & Serletis, 2011).

Also, a theory that criticizes fundamental and technical analysis is RWT which states that stocks always trade according to their fair value, meaning that is impossible for shareholders to buy or sell a security below or above its fair price. This theory is based on the premise that all available information is reflected in the share price and so the price at *t* moment is independent of one at *t-1*, making them uncorrelated and unpredictable. So, those who follow this theory cannot outperform the market without being induced into additional risk (Chitenderu et al., 2014).

Furthermore, RWT states that there must be at least measures when comparing two securities in a portfolio. On a basic level, these measures are presented by **return** and **risk**. To facilitate the comprehension of these concepts, a normal distribution (or bell curve), represented in Figure 9, constitutes the basis for modeling a population with fixed predetermined parameters (Lee et al., 2015).

Figure 9 Normal distribution in RWT, with mean (μ) and standard deviation (σ)



Source: Adapted from Lee et al. (2015)

The measurement of **return** can be attributed to the mean or average (μ). There are several ways in which experts can compare the averages, but the most used ones are the arithmetic and geometric (Zvingelis, 2019):

- The arithmetic average ($\bar{r}_A$) has the property of having an increase in confidence intervals the longer the period of data analyzed which is calculated as if they are not dependent or correlated. The variable, r_t can be described as a rate of return, for a given period, *T*:

$$\bar{r}_A \equiv \frac{\Sigma_{t=1}^{T} r_t}{T} \qquad (2)$$

- The geometric average ($\bar{r}_G$) it is more suited when calculating average returns in finance because it takes into consideration compounding occurring from period to period and the longer the time horizon, the more appropriate this variable becomes. The rate of return (r_t) for a set period (*T*) is defined as:

$$\bar{r}_G \equiv \left(\prod_{t=1}^{T}(1+r_t)\right)^{\frac{1}{T}} - 1 \quad (3)$$

Now, concerning the measurement of **risk**, it can be given by an expression for data dispersion, or volatility of a security. Having a data set of positive numbers, it can be described as the sum of the squared difference of a number from its average, divided by the number of values analyzed – the variance (σ^2).

Since the variance is not in the same units as the mean, a way to go around this problem is by adding a square root into this formula and the new variable is called standard deviation (σ). This new variable is the key to determining the risk or volatility of the price. A low value in this variable reflects prices being closer to the mean and a high reading on standard deviation means the prices are more dispersed relative to the mean. Also, for assets with the same return, rational investors would prefer those with lower risk (G. W. Brown, 1982; SEI, 2014).

The formula below represents the standard deviation, where x_i is the actual return on investment, μ represents the mean and *n* is the number of data (prices) analyzed:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \mu)^2}{n}} \quad (4)$$

The choice of this model is attributed to some advantages in this theory namely Shleifer (2000) states that there are rational investors that invest rationally, those who are irrational and trade randomly, and others that are irrational but sometimes make rational decisions, meaning that stock prices are unpredictable and supporting this theory. Also, Fama (1965) points out that investors cannot achieve long-term profitability using solely technical analysis when predicting price movements and Malkiel (2003) adds that even if investors achieve higher returns than the benchmark, they are not able to do it on a consistent basis.

Nevertheless, one argument that can dethrone this theory is the “Halloween Effect” proposed by Bouman and Jacobsen (2002) referred to when the stock market has better returns from October 31 to May 1 in contrast with from May to the end of October, meaning that the seasonality fallout may suggest a more predictable approach to the market. Furthermore, Couto et al. (2021) seem to agree with the previous iteration, arguing that investors with a diversified portfolio benefit from the “Halloween Effect” with an average monthly excess of 1.2% in winter and spring, while more significant in the pre-dot-com bubble.

3.1. Geometric Brownian Motion

In 1827 Robert Brown noticed that small particles of pollen, under a diluted solution, had an irregular path when observed through a microscope. Not he nor other scientists could fully understand or explain the phenomenon until Albert Einstein, in 1905, figured out that shocks from the liquid against the pollen would result in the randomness of the movement. These random movements gave strength to Brownian motion theory (Stachel, 1989).

Some academic research was performed concerning Brownian motion but the one that most applies to this essay is the **Geometric Brownian Motion (GBM)**. In 1965 Samuelson transforms an arithmetic BM into a geometrical one, through the association of the market efficiency hypothesis (Ramos et al., 2019).

This process is a derivation from the RWT that uses continuous-time stochastic processes (compilation of random variables) where the algorithm is a Brownian motion with drift, which is useful to determine population growth and financial models (Ladde & Wu, 2009).

A representation of this GBM is said to be a stochastic process (x_t) if it satisfies the condition:

$$\begin{cases} dX(t) = \mu X(t)dt + \sigma X(t)dW(t) \\ X(0) = x \end{cases} \tag{5}$$

These variables can be associated with those described in RWT, but according to this theory, μ is the drift, σ is the volatility and $W(t)$ is a basic BM variable (or Wiener process as it is named). In this first part of the equation (5), the predictable part that refers to the direction of the tendency is given by $\mu X(t)dt$ and the unpredictable parte wich is the "random volatile noise" is represented by $\sigma X(t)dW(t)$ (Yang & Aldous, n.d.).

Some properties can be attributed to this function, such as:

$X(t)$ is a continuous function;

The values are given by $X(t)$ have uncorrelated increments from $X(t-1)$;

When $t > s \geq 0$, the addition follows a normal distribution equal to $X(t+s) - X(s) \sim N(0,t)$.

Also, regarding the expected price of the model, the daily drift and volatility can be attributed to functions (6) and (7) (Guloksuz, 2021):

$$\hat{\mu} = \frac{\bar{x}}{\Delta t} + \frac{\sigma^2}{2} \quad (6)$$

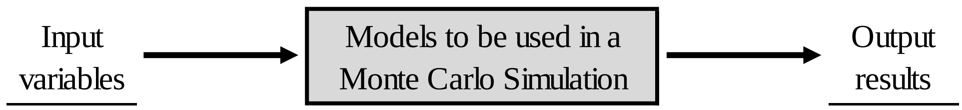
$$\hat{\sigma} = \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (7)$$

4. Monte Carlo Simulation

Nowadays statistical models are incorporated in mathematical, computational, and analytic procedures in order to create different outcomes and probabilities when dealing with different variables.

One of these methods can be described as a Monte Carlo Simulation (MCS) or Monte Carlo Methods. Through the introduction of one or more variables (called the inputs) and then performing hundreds of thousands of simulations, the model gives the outputs, so that experts can interpret the different results and adapt the best model to be used. A representation of this model is shown in Figure 10:

Figure 10 Monte Carlo Simulation model



Source: Self-elaboration

The Monte Carlo simulation is a good instrument to explore and decrease uncertainty among different results and is useful when calculating the results that are codependent, conditional, or nonlinear.

Nevertheless, there are some limitations to this approach, namely:

- The output variables created by the model make no sense if our inputs do not show an appropriate approach to deal with the problem, meaning that variables created (outputs) are not backed by solid variables introduced (inputs);
- The most used statistical variable used – the mean – on finance exercises, may not have a significant impact on the simulation result since sometimes we cannot differentiate the use of a mean statistics with static calculations instead from a

mean statistics applicable to MCS wich is constantlychanging due to the unpredictability factor to this model.

Presently, the outcome of this model solves the randomness and certainty, which are the main problems when dealing with future scenarios. Furthermore, when dealing with this, the most widely variable used is the **geometric mean** to estimate results, linked to the **Geometric Brownian Motion**, the most accredited method (Beaton & Sawyer, 2019; Roy & Sinha Roy, 2017).

Chapter 3 – Empirical study

"Hard times create strong men, strong men create good times, good times create weak men, and weak men create hard times" - *G. Michael Hopf*

This part starts with the past analysis of the ETFs mentioned in Table 4 as well as the benchmark that tracks the MSCI World Index.

Firstly, it is described how the data retrieved is analyzed. Secondly, it is stated how the inputs chosen, the **geometric mean** and **standard deviation** are calculated in the Excel spreadsheet, in order to achieve the methods proposed. Lastly, it is described how the Monte Carlo simulation is conceived and a summary of key comparison metrics are created.

1. Past performance

Before the analysis of the different metrics of the ETFs, a thorough image should be depicted of them, relating their past performance in the equity market. This is the starting point that serves as input to the simulation model.

The variable that is examined first is the monthly price of the ETFs from 01/01/2010, until 31/12/2021. Regarding this variable, it should be considered the closing price, since is the information that investors and managers take into consideration[6]. Also, the information on the closing price is analyzed as an **annual** variable. The calculations are reflected after the study of 145 different prices - prices retrieved from monthly performances and then converted to annual returns - for a single fund, and, whenever possible should the market price be taken into consideration instead of the NAV of the fund.

[6] Although some funds had company actions, for instance a 1:10 reverse stock split of TAN on 15/02/2012 and a 1:2 reverse stock split of LIT on 18/11/2015, dividends and distributions, this information is fully adjusted on the closing price.

Furthermore, the price of the different ETFs can be accessed through the website of the respective Fund, such as BlackRock for ICLN and SWDA, Invesco to retrieve the information from TAN and PHO, First Trust for FAN, and LIT is recovered from Global X. The companies offer access to an Excel spreadsheet where it is easier to calculate performances and other metrics useful to the initial hypothesis.

Although the funds have publicly available data, sometimes it is not fully disclosed to retail investors, leaving analysts wondering if there is an alternative way to access this data. Luckily the gap in the data was avoided by using the Bloomberg Terminal, a financial platform used worldwide to analyze the market. The data is then grouped from the funds' inception date until the last available traded date – so, the information should be narrowed down to the desired period.

As a consequence, the data is analyzed in an Excel spreadsheet and all the calculations are performed in this format along with the explanation of the formulas used and why they were specifically used.

2. Calculate the Geometric Mean and Standard Deviation

After downloading the closing prices from Blomberg Terminal, we calculated the geometric mean and the standard deviation, which represent the fundamental metrics that serve as input to the Monte Carlo Simulation. Also, as a matter of reference to the geometric mean, a calculation of a simple average is performed but does not constitute evidence to calculate future performances.

To calculate these metrics, firstly we determine the annual return, and to do so the formula is $\mathbf{(P_t\text{-}P_{t\text{-}1})/P_{t\text{-}1}}$, where P_t represents the price at the beginning of the year *t* and P_{t-1} is the price at the beginning of the previous year, and then convert this value to a percentage. After that, we determine the simple average as the average of those annual returns.

In order to account for the geometric mean, a column should be added to the spreadsheet and calculate the logarithm of the annual return, because it gives the true representation of a log-normal distributed function, since the objective is to determine the compound interest and not the simple interest between two periods. After, we calculate the average of the **+LN(P_t/ P_{t-1})** formula and the standard deviation of a given sample, with the formula **+STDEV.S()**, of the ln column because it constitutes the standard deviation of a given sample. In Figure 11, an example of these calculations is presented for the *MSCI World Index* and the **+FORMULATEXT()** function, in orange, shows the formula applied in the left column - for the arithmetic mean, geometric mean, and standard deviation respectively. The procedure is then also applied to the remaining five ETFs.

Figure 11 Metrics that serve as input in MCS

	A	B	C	D	E	F	G	H	I	J	K
1											
2	**ETFs**										
3	**Past monthly results**										
4	Data retrieved from Bloomberg										
5											
6	**Date**		**MSCI World Index**								
7											
8				Monthly stock return	Yearly stock return	Ln	Yearly				
9	31/12/2021		$ 3,231.73	4.19%	20.14%	18.35%	**Mean (A)**	9.48%		=+AVERAGE(E:E)	
10	30/11/2021		$ 3,101.80	-2.30%			**Mean (G)**	8.48%		=+AVERAGE(F:F)	
11	29/10/2021		$ 3,174.73	5.59%			**Std. Deviation**	11.35%		=+STDEV(F:F)	
12	30/09/2021		$ 3,006.60	-4.29%			*Annual				
13	31/08/2021		$ 3,141.35	2.35%							
14	30/07/2021		$ 3,069.25	1.72%							
15	30/06/2021		$ 3,017.23	1.40%							
16	28/05/2021		$ 2,975.70	1.26%							
17	30/04/2021		$ 2,938.76	4.52%							
18	31/03/2021		$ 2,811.70	3.11%							
19	26/02/2021		$ 2,726.91	2.45%							
20	29/01/2021		$ 2,661.69	-1.05%							
21	31/12/2020		$ 2,690.04	4.14%	14.06%	13.15%					

Source: Self-elaboration, with prices retrieved from Bloomberg Terminal

3. Portfolio Forecasting

On the next spreadsheets - more specifically six, one for each fund – we calculate the parameters for the MCS. Firstly, a set of assumptions are created to build the expected future value of the investment. Then the simulation is performed, with a total of 255 trials for each fund, and is where future estimated values are organized. The final step is to calculate the probability of each fund achieving a higher estimated future value than the benchmark, including the contributions over the thirty-year period.

3.1. Assumptions

In this array (cells D6 to D10), a set of different premisses are established to create the future value of the portfolio. To define these assumptions it is considered an investor that has the ability to save some income - assuming a $200 saving at the end of the month – for investing in the stock market. He/she is willing to make an initial deposit of $1,000 with $2,400 in contributions at the end of the year. The other important assumptions are the geometric mean, the standard deviation, and how much time, in years, is the investment compounded, as demonstrated in Figure 12.

Figure 12 Assumptions when creating the MCS, for the benchmark index

Security: MSCI World Index (MXWO Index)

Assumptions	
Initial Investment	$ 1,000.00
Annual Investment	$ 2,400.00
Mean (G)	8.48%
Std. Deviation	11.35%
Years	30

Source: Self-elaboration

To create a model with the value of the portfolio at the end of the thirtieth year, a table is created with three columns, in which the left is the number of years, from 1 to 30, the middle is the expected return, in percentage, and the other column is the expected future value (EFV), that is calculated after the second column. For the expected return the formula used is the **+NORMINV(RAND();μ;σ)** and the expected value, in the first year is **+1,000*(1+ER)+2,400**, where ER is the expected return for that year. As for the remaining EFV, the formula is similar, with the only change regarding the initial of $1,000 to the previous year's EFV.

This table, in Appendix 3, represents a single iteration from the simulation and constitutes a single base case. For the next step, the simulation should be created, having the base case as an example.

3.2. Simulations

Following the assumptions about the model, we create different simulations for the various study periods. To do that, a double-entry table is created where on the horizontal line are the number of years of the model and on the vertical line are the number of simulations the excel performs, and for this thesis, **we run a total of 255 iterations**, for each fund. The reason for this specific number of simulations is related to the maximum amount of data series per chart. This is what constitutes the Monte Carlo simulation since the input variables are known - mean and standard deviation - and the model is the one described.

For the second row of the double-entry table, the first is the one with the periods of study, the values from EFV are transposed and the formula used is the **+TRANSPOSE()**[7] to copy the data with the same format.

The next step is to create two hundred and fifty-five simulations for the investment portfolio, for a single year and then for every year. Since in excel it is simpler to calculate all the simulations for all the tables instead of a single year, the propper way is to highlight the table from the second row to the end of the table and do a What-if Analysis[8].

This procedure is then repeated on every fund to calculate the probability of having higher returns than the *MSCI World Index*.

3.3. Statistical calculations

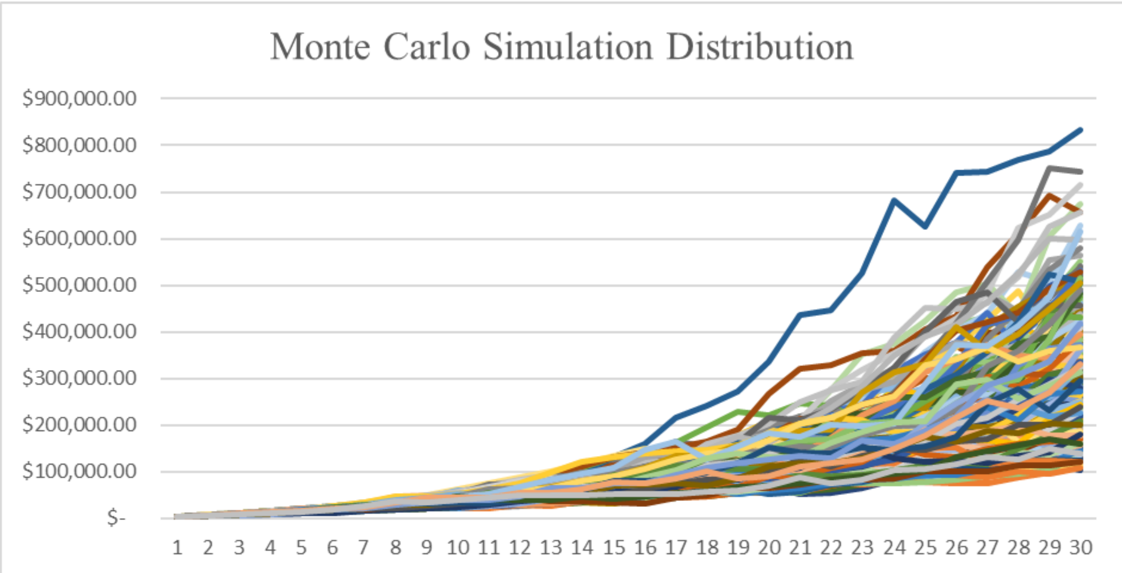
Since the data might be hard to decipher at a first glance, we create a graph where all the simulations are projected to the respective thirty years period. A representation of this MCS on the MSCI World Index can be represented in Figure 13, but since this is a simulation with a random variable - **rand()**, every time the excel sheet is changed or F9 is pressed on the keyboard, the simulation recalculates the value of the portfolio.

[7] For this exemple, first the cell that will be transposed are highlighted. Then it is introduced the formula +TRANSPOSE(x), where x is the array from EFV. Finally instead of pressing “Enter”, it is used the ”Ctrl+Shift+Enter” because is more effective when on working with arrays.

[8] In this step we select the Data table option and then for the column input cell we selecte a cell outside the table.

Regarding these new values, it is imperative to calculate some statistical calculations, such as probabilities, since projections do not always coincide with reality. Firstly we calculate the median, since is a good indicator in future projections, and then the arithmetic average. The reason why the arithmetic average is considered is that it is a comparison tool for the median, and although not relevant to the study its values are close to the median in the early years, but the divergence becomes wider, the more it goes on, evident in Appendix 4. Next, the percentiles of 0.3%, 5%, 10%, 25%, and 50% are calculated for each year, meaning for a given percentile (Pi) there is a 1-Pi chance of success. This means, for instance, in a five percent percentile, there is a ninety-five percent chance of achieving a certain portfolio valuation.

Figure 13 All 255 MCS for the *MSCI World Index*



Source: Self-elaboration

To all the clean energy ETFs we then create one of the the most important metrics which determines the probability of achieving higher returns than the benchmark. The function used in Excel is the +countif, where it is calculated the number of times the 255 simulations achieve a higher EFV than the *World Index* median.

Chapter 4 - Discussion of results

"People think of Tesla as an electric car company but the whole purpose of Tesla was to accelerate the advent of sustainable energy." - *Elon Musk*

In this section, an overview of the results obtained is discussed. A table is presented along with key metrics that the author found relevant to be discussed. The goal is not to extrapolate conclusions but to analyze the obtained results.

1. Summary of obtained results

After the calculations in the Excel sheets were performed, it is time to analyze the obtained results. For that we take a look at the inputs from past results, clear in Table 5, and future results such as the median, probability of achieving higher returns than the benchmark and the final EFV of the portfolio, present in Table 6.

Table 5 Past result's metrics for the different ETFs

	Past results	
ETFs	Geom. Average	Std. Deviation
MSCI World Index (MXWO Index)	8.48%	11.35%
iShares Global Clean Energy ETF (ICLN)	-0.42%	39.81%
Invesco Solar ETF (TAN)	-2.39%	64.65%
First Trust Global Wind Energy ETF (FAN)	2.49%	27.33%
Invesco Water Resources ETF (PHO)	10.69%	16.21%
Global X Lithium & Battery Tech ETF (LIT)	7.74%	36.06%

Source: Self-elaboration

Regarding the geometric average, the benchmark and three other funds present a positive rate, which has a positive impact on the growth value of the portfolio. The ones that do not have this positive tendency are the broad ESG ETF - iShares Global Clean Energy ETF - and the Solar ETF - Invesco Solar ETF - that consequently have a negative impact on the performance of the portfolio.

For the standard deviation, all of the ETFs have higher divergences from the mean compared to the benchmark. This can reflect the price volatility that, in the short to medium term, they might experience. The least volatile ones, meaning the ones that have a lower percentage on this metric are the ICLN and PHO.

Table 6 Key takeaways from the Monte Carlo simulation

	Future results				
ETFs	Arith. Average	Median	Probability *	Final portfolio value	Cost of opportunity
MSCI World Index (MXWO Index)	8.46%	7.97%	-	$ 280,156	$ 207,156
iShares Global Clean Energy ETF (ICLN)	0.73%	-6.25%	5.88%	$ 33,005	$ -39,995
Invesco Solar ETF (TAN)	-12.32%	-22.48%	1.18%	$ 10,672	$ -62,328
First Trust Global Wind Energy ETF (FAN)	2.95%	-0.09%	7.06%	$ 72,093	$ -907
Invesco Water Resources ETF (PHO)	10.76%	10.04%	72.16%	$ 415,105	$ 342,105
Global X Lithium & Battery Tech ETF (LIT	7.81%	2.38%	21.96%	$ 105,454	$ 32,454

* Probability of achieving higher returns than benchmark median

Source: Self-elaboration

Regarding the median, this reading should be the **comparison metric** instead of the arithmetic average. It means that is more representative than the average when creating future projections. The median values are lower than the mean presented, not only for the positive ones but for the negative percentages as well. This might have been due to two reasons, the period studied for future results is greater than the period analyzed for past results and the annual contributions can have an impact on the profit/loss percentage, every time a new year begins.

2. MSCI World Index (MXWO)

The benchmark represents the comparison fund for all of the other ETF categories. It is a steady rise fund that from the beginning of 2010 to the end of 2021 generated almost 8.5 percent of annual return with a standard deviation of 11.35 percent, meaning that it has the lowest levels of volatility of all the funds considered when comparing the values from Table 6.

Table 7 MSCI World Index metrics

	Past results		Future results				
ETFs	Geom. Average	Std. Deviation	Arith. Average	Median	Probability *	Final portfolio value	Cost of opportunity
MSCI World Index (MXWO Index)	8.48%	11.35%	8.46%	7.97%	-	$ 280,156	$ 207,156

Source: Self-elaboration

Table 8 Aditional metrics including percentiles – MXWO Index

Statistical projections for 30th year				
Risk + return	Espected FV	CAGR	Percentiles	Espected FV
Average (A)	$ 307,439	8.46%	0.3%	$ 106,540
Median	$ 280,156	7.97%	5%	$ 139,543
			10%	$ 157,106
			25%	$ 204,620
			50%	$ 280,156

Source: Self-elaboration

In the future results, represented in Table 7 and Table 8, the most important metrics are the **median**, the **final portfolio value**, and the **opportunity cost** or return on invested capital, which represents the excess or lack of the amount invested, that is $1,000 + $2,400*30 years = $73,000.

The median is in line with the past results' geometric average. For the final value of the portfolio that would be close to three hundred thousand dollars and if someone would have not chosen this Index, the return on invested capital would have been as high as (in theory, since one cannot invest in an Index, just, in this case, an ETF) $207,156 in profits, evident on Table 7.

The compound annual growth rate (CAGR) in the table represents the average rate of return from the beginning of the investment period to its end and is shown in Table 6 as the arithmetic average.

Also and since the meaning of the calculations is to provide as much information as possible about the securities that are invested, in Table 8 there are also some **percentiles** or chances of success for achieving certain expected future portfolio value. For instance, there is a 99.7% chance (100% - 0.3% that represents three standard deviations from the mean and encompasses almost the entirety of the sample) of achieving $106,540, a 95% chance of having $139,543, and a 50% probability, or median, of having $280,156 at the end of the 30th year.

3. iShares Global Clean Energy ETF (ICLN)

Table 9 iShares Global Clean Energy ETF metrics

	Past results		Future results				
ETFs	Geom. Average	Std. Deviation	Arith. Average	Median	Probability *	Final portfolio value	Cost of opportunity
iShares Global Clean Energy ETF (ICLN)	-0.42%	39.81%	0.73%	-6.25%	5.88%	$ 33,005	$ -39,995

Source: Self-elaboration

Table 10 Aditional metrics including percentiles - ICLN

Statistical projections for 30th year					
Risk + return	Espected FV		CAGR	Percentiles	Espected FV
Average (A)	$	81,464	0.73%	0.3%	$ -10,447
Median	$	33,005	-6.25%	5%	$ 5,750
				10%	$ 8,674
				25%	$ 16,659
				50%	$ 33,005

Source: Self-elaboration

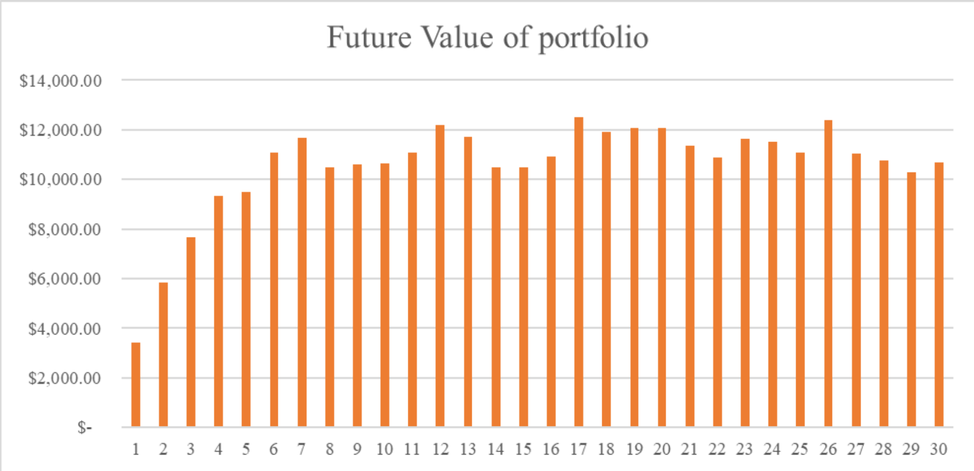
The broad ESG represented by the iShares Global Clean Energy ETF can depict a wider picture of the global trends in ESG investing. Throughout the period of study, from 2010 to 2021, Table 9 depicts that although the standard deviation is higher than the benchmark, the mean is lower and slightly negative. A study from Mehra (2019) also indicates that green ETFs have a close to zero average means, although some thematic ETFs present higher returns when compared to funds within the same investment theme. Furthermore, the work finds that broad ETFs have no compelling past performance although being seen as a diversified fund in the ESG category.

This conclusion is evident that if invested in this fund, it would have an unrealized loss of $40,000 on capital invested and a median value portfolio value of $33,005. According to the percentiles in Table 10, the most likely scenario is the 5% percentile which yields a final portfolio value of $5,750, since there can be no negative values in this table, which excludes the 0.3% percentile.

4. Invesco Solar ETF (TAN)

Through the analysis of the past values, it is concluded that the median value of the future portfolio is around $10,600 which corresponds to a negative rate of return of 18.33%, present in Figure 14 and Table 11. These negative metrics contradict the work from Sahu (2017) that concludes there is an enormous potential for the growth of this sector, especially in emerging markets where governments take measures to develop certain types of solar energy thus making the power prices gradually lower.

Figure 14 Future value of the portfolio, if invested in TAN, by year



Source: Self-elaboration

One explanation for why the investment in this ETF yields a low return is that from 2010 to 2012 the return on this fund was negative and from that period onwards it started to trade in a range, but only at the end of 2020 the price was finally higher than what was in the beginning. Of all the ETFs analyzed this has the lowest probability of achieving a higher value than the benchmark median.

Table 11 Metrics including percentiles - TAN

Statistical projections for 30th year							
Risk + return	Espected FV		CAGR		Percentiles	Espected FV	
Average (A)	$	19,116	-12.32%		0.3%	$	-475,126
Median	$	10,672	-22.48%		5%	$	-14,154
					10%	$	1,509
					25%	$	4,298
					50%	$	10,672

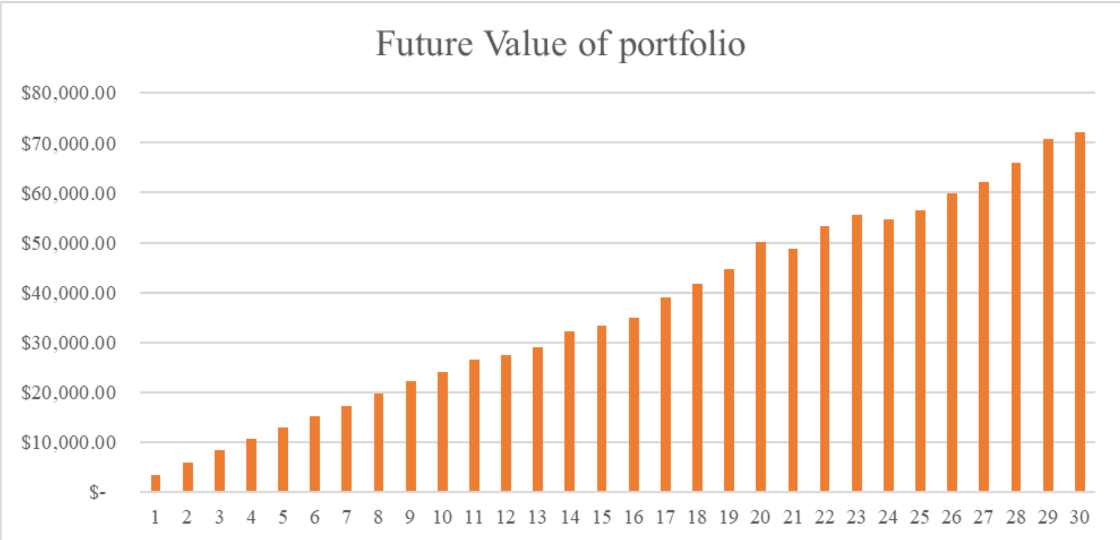
Source: Self-elaboration

5. First Trust Global Wind Energy ETF (FAN)

As far as the Wind ETF performs it has a steady growth throughout the years as represented by Figure 15, but this can be misleading since the value of approximately

$70,000 is achieved through the annual contribution and not from the rise in the price of the ETF. Although the report from Gannoum et al. (2019) states that the evolution of this sector has been on a remarkable rise in the last decades, it does not reflect the inflows to this ETF. One possible reason is that investors may find other sectors more attractive than wind technologies since the basket of companies related to this sector did not increase in value as a whole.

Figure 15 Future value of the portfolio, if invested in FAN, by year



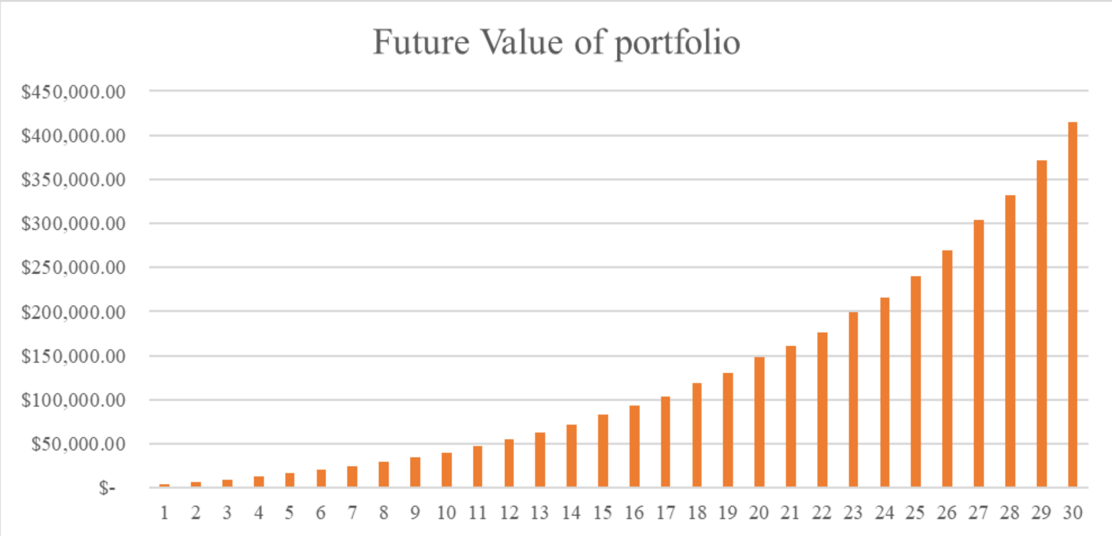
Source: Self-elaboration

6. Invesco Water Resources ETF (PHO)

For the representative of the water sector, this fund has the highest probability of achieving a greater return than the benchmark. According to Table 6, Figure 16, and Table 12, it is clear that the returns provided by this ETF are gradual the slope's curve is similar to the benchmark. This finding is in line with the one stated by Byre and Kverneng (2017) that hydro had outperformed the market from 2009 to 2017.

One additional finding is that as water becomes more scarce, the price of the companies involved in this sector tends to have a higher return. Also, since it has the lowest standard deviation of the clean energy funds considered, the volatility is close to the benchmark's volatility.

Figure 16 Future value of the portfolio, if invested in PHO, by year



Source: Self-elaboration

Table 12 Metrics including percentiles - PHO

Statistical projections for 30th year						
Risk + return	Espected FV		CAGR	Percentiles	Espected FV	
Average (A)	$	477,508	10.76%	0.3%	$	74,088
Median	$	415,105	10.04%	5%	$	131,267
				10%	$	161,593
				25%	$	269,266
				50%	$	415,105

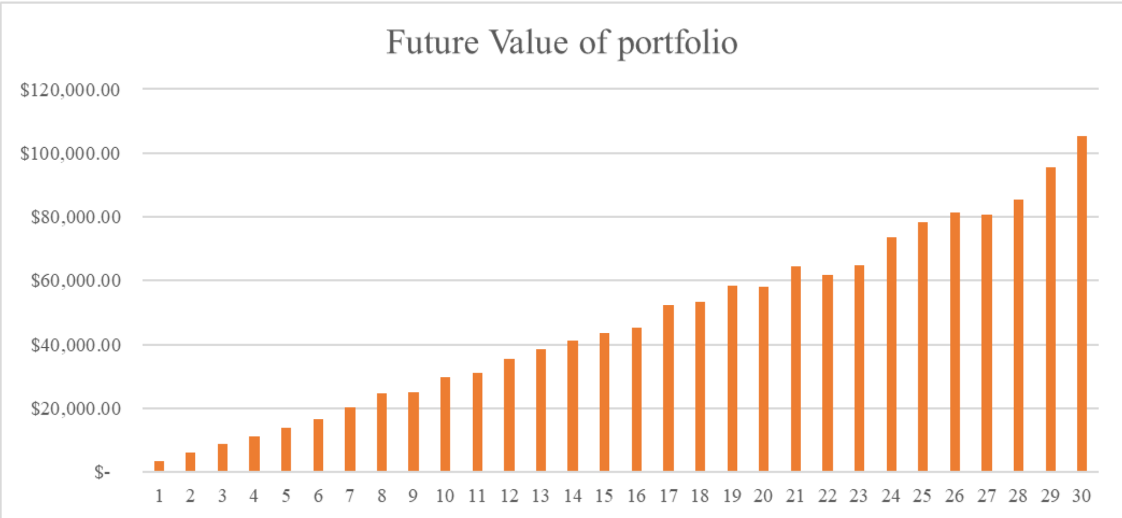
Source: Self-elaboration

7. Global X Lithium & Battery Tech ETF (LIT)

The representative fund of the lithium sector has a lot of growth potential due to the start of EVs becoming more mainstream. It is evident from Table 6 and Figure 17 that there is a probability of around twenty percent of achieving higher returns than the benchmark index.

A study provided by Pereira (2018) confirms that electric vehicles are a future-oriented industry that brings positive economic impact since we are in the early stages of EV adoption. Whether a large portion of society is determined to reject vehicles that use fossil fuel, it becomes a catalyst for the acceleration of goods and services related to lithium research and investment, and, it is only possible through the incentive of companies and governments. Also, Rangarajan et al. (2022) cite that the research on lithium-ion materials have risen exponentially in the last decades and as new paths are being explored, it will lead to a more significant impact on our lives

Figure 17 Future value of the portfolio, if invested in LIT, by year



Source: Self-elaboration

Conclusions, Limitations and Future Perspectives

This work presents an interpretation if an investment in a fund that encompasses all the investable companies in the world surpasses the investment in a broad ESG fund or whether it is better to invest in renewable categories individually. To do so, the main objective of this thesis is to forecast the probability of a selected group of clean energy ETFs achieving higher future performance than the broad market. Also, further additional goals aim to study the past performances of all the funds as well as predict their future values for a thirty-year period.

For that, this work is divided into three chapters. The first one is dedicated to the definition of exchange-traded funds, namely what they are and how they have come into existence and become a very popular investment. Also, the types of ETFs are discriminated, as well as how they are created and redeemed through the primary and secondary market and the risk inherit that an investor has by holding this asset. These assets are becoming a source of inflows from institutions and retail investors because they are inexpensive, transparent, and tax-efficient (Gastineau, 2004). Also in line with responsible awareness in the investment is sustainable finance, where executives create policies that benefit ESG practices (Migliorelli, 2021).

Then a definition of Environmental, Social, and Governance is provided along with measurements that major raters find relevant. The next subject regards a connection between the two previously mentioned topics, creating the topic of clean energy investing and the main focus is to better comprehend the types of renewable energy sources, such as solar, wind, hydro and electric vehicles technology, the role of governments and institutions in promoting these renewable energy infrastructures and to discriminate some keywords associated to sustainable investment.

It is evident how the use of fossil fuels has impacted our lives, it is a major player in the emission of GHG and contributes to global warming. That is why a debate towards clean energy practices is increasing awareness and worriness about the future of the planet (Rizzi et al., 2014).

The second chapter is dedicated to the methodology that serves as the base case to the primary objective thesis – to predict if it is better to invest in the world benchmark or in some selected clean energy ETFs. So, firstly past performances are analyzed from January 1st, 2010 to December 31st, 2021 to hypothesize future price returns into a thirty-year projection.

The beginning of this chapter starts by stating some selection criteria of the funds picked and why the twelve-year time period is considered. It is followed by an explanation of the theory that supports this work – the Geometric Brownian Motion, which is a derivation of the Random Walk Theory. These methods state the main inputs for the model which are the geometric mean and the standard deviation.

Following the previous subject, there is an explanation of how the model is applied to an Excel spreadsheet, which is through a Monte Carlo Simulation. From there, a set number of random simulations are performed in order to determine the expected future value of the World Index and the clean energy funds.

The third chapter regards the discussion of obtained results, in which there is a comparison between the benchmark and the other selected clean energy ETFs. Firstly, there is a general overview of what the simulation shows and then there is an extensive description of how each individual fund performs in the future projection.

As for the main objective of this thesis, that is whether is better to invest in the *MSCI World Index* or in some selected clean energy ETFs. To achieve that, past performances are analyzed, and then through the use of the geometric mean and standard deviation, some predictions are extrapolated to create future performances, based on median values.

Besides the main objective, there are two additional goals that are intended to be answered by the methods used. The first one regards the past performances during the period of study that encompasses the European Sovereign Debt Crisis and the Coronavirus Crisis 2019. The second one regards what the expected future median value of the funds analyzed will be. Although they are the secondary objectives of this thesis, they heavily impact the primary goal.

For the broad market, depicted by the *MSCI World Index* (MXWO) the median EFV is $280,156, with an annual growth rate of around 8%. Having that as a baseline for the comparison with the clean energy funds there are some outputs that the model has returned.

For the broad clean energy (ICLN) it is noticeable that past performances have a negative impact on the return of this ETF. So, the probability of surpassing the broad market is as low as a 5.88% chance of success with a final portfolio value of $33,005. This drawdown does not reflect what Rizzi et al. (2014) argue, that the general population is trending to a more sustainable way of living because of what could happen to the future of the planet Earth. One possibility of why this does not apply to this ETF is that past performance reflects an almost flat negative geometric mean of -0.42% and a high standard deviation.

For the Invesco Solar (TAN) there is a 1.18% chance of having a higher return than the broad market and the final portfolio value is $10,672. It is evident that the past results impact negatively this fund as well as having the highest standard deviation from the ETFs chosen. It constitutes a bad investment since at the end of the thirtieth year there is an unrealized loss of $62,328.

Regarding the First Trust Global Wind Energy (FAN) around 7 in 100 simulations surpass the median value of the benchmark. Although having a low mean of 2.49% on past results, the median percentage can be negative due to the standard deviation.

Now for the Invesco Water Resources (PHO) there is a very high probability of surpassing the global market index. In fact, this ETF has the highest probability of 72.16% and has a final portfolio value of $415,105, which constitutes a higher median than the benchmark. Fruitfully this is achieved by a geometric average from past results of 10.69%. A possible takeaway is that this energy source is the biggest one from the renewable energy pie and is well established, so it becomes a crucial element if the goal is to produce more efficient energy that comes from RES (World Energy Council, 2016).

For the last ETF analyzed, the Global X Lithium & Battery Tech (LIT), it is concluded that this fund has a probability of achieving a 21.96% higher returns than the broad market. The geometric mean of 7.74% is what gives the EFV of $105,454. This is influenced by the rise of electric vehicles as an alternative to fossil fuel vehicles, and although this is a new technology, car companies are transitioning their fleet to a more sustainable means of transportation as argued by Sovacool et al. (2019).

So, the outcome of the model proposed gives the PHO and MXWO a stable expected return since those are the ones that provide the highest final portfolio value. For the worst long-term investment in clean energy can be attributed to TAN and ICLN.

From an investor perspective, it is better to invest in a water ETF such as PHO and be exposed to a world index ETF such as MXWO and for a poor long term investment in the clean energy space, there is the solar ETF, TAN, and the broad ESG fund represented by ICLN.

Another way to interpret these performances is despite having an allocation to all of the funds analyzed, an investor can have higher exposure to those who had positive returns to offset the losses in those who perform poorly.

These findings are in line with the work of Byre and Kverneng (2017), stating that from 2009 to 2017 only hydro have outperformed the market and nevertheless, the annualized mean return is in line with the market, not achieving a significant divergence in this variable.

Also, the conclusions proposed by this work are partially consistent with the findings of Mehra (2019) that studies the past performance of green ETFs and concluded that they have flat or negative returns, although some of them present higher yield than the group average. Although in this thesis, some funds' past performances are flat like the ICLN or negative like TAN, they do not constitute a majority and only PHO has a significant difference in the mean value in comparison to the benchmark.

This thesis can be helpful to the existing literature regarding investing in a world index and in exchange-traded funds that have exposure to the broad clean energy landscape, solar, wind, water, and lithium. The findings provided are constructive to those who would like to have access to these assets and better understand how they function.

As for the limitations of this study, there are three major ones. The first can be attributed to the fact that the investment thesis for the of analyzed funds might greatly narrow the sample. For instance, PHO ETF has a 98% exposure to Unites States-based companies which disregards other companies from around the world that might have better performances than the ones the fund hold. Although even if funds are in the same clean energy sector between two or more ETF providers the returns should not have a great divergence since the funds' holdings can be very similar to one another.

The second is a major factor as regards the analysis period of the selected funds. It constitutes the main factor for future performances and if, for instance, the funds achieve a better performance in the last years of the period of analysis, the return becomes insignificant due to the extensive annual period studied.

The third one is the fact that Excel can only encompass, in the simulation graph, no more than 255 iterations, which constitutes a major obstacle because it can be argued that the sample amount is not representative enough. Although other studies that include the MCS in their work may present more simulations but use a different program, such as Python, or paid add-ins in the Excel program.

For future perspectives, similar studies can focus on a more narrow period, such as the period that only encompasses the covid crisis since a lot of funds had substantial returns in 2020. Also, it is a good measurement if future research encompasses the inflation factor in the portfolio, meaning how future performances may be adjusted for inflation as 2019 as the base year.

can be impacted by the inflation caused by the covid crisis.

Lastly, there can be a replication of this study by using more funds and comparing them to a different benchmark. It would be appropriate to change to the S&P 500 Index since every ETF has some degree of exposure to the United States of America and is one of the funds that attract a lot of investors.

Clean energy investment is at an early stage and with more awareness from the population toward a more sustainable planet, humanitarian conflict in Western Europe, and the European Union designing a plan to eliminate the dependency on Russian oil, there is an enormous potential for the prices of sustainable funds to grow. Therefore the role of companies and governments to promote desirable infrastructure in regard to sustainability becomes a crucial factor.

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Appendices

Appendix 1 ETF issuers by AUM

Issuers	Fund Flow Rank	+/-	3-Month Fund Flow (MM)	Return Rank	Avg 3-Month Return (%)	AUM Rank	Assets Under Management (MM)
Blackrock Financial Management	3	38	6,909,130.00	79	260%	1	223,768,243.00
Vanguard Group Inc	1	-	10,653,502.00	70	343%	2	166,322,764.00
State Street	5	-	3,053,777.00	38	665%	3	87,657,751.00
Invesco Fund	6	1	1,584,189.00	97	143%	4	33,285,537.00
Charles Schwab	7	1	1,165,394.00	49	474%	5	23,583,945.00
First Trust Advisors LP	8	1	618,872.00	98	139%	6	12,205,040.00
Vanguard Group Inc	13	-	231,174.00	50	473%	7	10,000,100.00
World Gold Council	160	-	-634,317.00	109	4%	8	6,507,607.00
JPMorgan Chase	159	-	-539,844.00	61	379%	9	6,090,579.00
Van Eck Associates Corp	10	-	403,384.00	65	363%	10	6,060,201.00
Proshare Advisors LLC	12	1	260,992.00	93	184%	11	5,487,766.00
Wisdom Tree Asset Management Inc	17	1	134,202.00	52	471%	12	4,441,964.00
ARK	14	-	196,542.00	159	-2861%	13	4,125,470.00
Mirae Asset	9	24	479,112.00	101	76%	14	2,908,196.00
Fidelity Management & Research Co	4	-	3,682,988.00	71	338%	15	2,809,447.00
Allianz Investment Management LLC	20	49	87,140.00	126	-26%	16	2,700,161.00
Rafferty Asset Management	2	-	7,419,145.00	22	832%	17	2,424,063.00
Goldman Sachs & Co/GSAM	156	16	-80,877.00	74	288%	18	2,290,547.00
State Street Bank and Trust Co/IFTC	42	37	13,438.00	28	769%	19	2,189,960.00
Deutsche Bank	18	-	124,126.00	95	174%	20	2,146,712.00
Northern Trust	15	-	155,066.00	23	823%	21	1,809,098.00
CICC	11	-	279,175.00	150	-1331%	22	950,509.00
Franklin Templeton	49	-	10,099.00	89	203%	23	937,469.00
SS&C	37	-	16,307.00	10	1337%	24	923,976.00
Standard Life Aberdeen	40	-	15,194.00	51	472%	25	724,372.00
ETFMG	24	-	57,142.00	148	-803%	26	710,005.00
Pacer Advisors	23	-	62,884.00	44	509%	27	697,264.00
Exchange Traded Concepts	28	4	46,348.00	145	-715%	28	659,788.00
Crestview	153	-	-5,591.00	27	774%	29	643,210.00
American Century Investments	16	-	143,401.00	34	711%	30	628,389.00
Grace Partners of Dupage LP	39	-	15,781.00	130	-144%	31	509,299.00
Innovator	30	-	40,911.00	99	138%	32	503,288.00
Manulife	155	-	-52,432.00	48	482%	33	494,604.00
Principal	22	-	64,181.00	63	370%	34	493,891.00
Amplify Investments	25	-	54,518.00	144	-660%	35	454,409.00
Concierge Technologies	157	-	-90,692.00	6	1517%	36	446,314.00
New York Life	44	-	13,008.00	91	190%	37	434,465.00
Janus Henderson	137	-	-490.00	127	-76%	38	416,299.00
The Hartford	152	-	-3,526.00	67	357%	39	399,408.00
US Global Investors	29	-	43,530.00	20	866%	40	395,722.00
TIAA	32	-	32,923.00	62	372%	41	381,082.00
Barclays Capital	21	-	84,404.00	142	-586%	42	324,472.00
Horizons	19	1	92,789.00	134	-324%	43	272,521.00
BMO Financial Group	158	152	-169,395.00	129	-114%	44	251,994.00
AdvisorShares	27	-	47,643.00	151	-1560%	45	227,446.00
Toroso Investments	43	32	13,030.00	124	-15%	46	198,971.00
Prudential	34	-	22,350.00	103	44%	47	160,020.00
Ameriprise Financial	41	-	14,973.00	133	-270%	48	153,693.00
O'Shares Investments	147	15	-2,062.00	136	-344%	49	151,740.00
GraniteShares	48	2	10,236.00	88	217%	50	151,404.00
Vident	144	-	-1,531.00	32	761%	51	150,671.00
Defiance ETFs	47	-	10,309.00	137	-405%	52	138,076.00
Dimensional Holdings	26	2	48,872.00	53	471%	53	133,748.00
Davis Advisers	61	-	4,822.00	41	567%	54	133,527.00
UBS Global Asset Management	148	15	-2,240.00	9	1362%	55	129,104.00
Aptus Capital Advisors	54	5	7,168.00	77	262%	56	119,970.00
Virtus Investment Partners	36	-	20,050.00	12	1195%	57	117,816.00
EMPIRICAL FINANCE LLC	63	8	4,466.00	139	-441%	58	108,309.00
Cambria Investment Management LP	45	1	12,959.00	37	673%	59	107,490.00
Main Manangement	38	4	15,958.00	72	305%	60	93,115.00
Inspire	50	-	9,667.00	54	441%	61	92,358.00
Credit Suisse Group AG	55	-	6,803.00	60	392%	62	87,713.00
Bank of New York Mellon	35	3	22,300.00	81	254%	63	80,230.00
Aegon	140	-	-874.00	59	400%	64	79,448.00
Nationwide	51	2	9,384.00	131	-179%	65	65,427.00
The Motley Fool	69	-	3,225.00	141	-553%	66	61,862.00
Roundhill Investments	52	-	9,153.00	143	-595%	67	61,140.00
Renaissance Capital	154	16	-23,598.00	156	-2350%	68	57,785.00
Rational Capital LLC	33	-	22,817.00	125	-21%	69	55,270.00
Tortoise	53	-	8,061.00	2	1759%	70	54,834.00
Merk	87	-	1,012.00	107	11%	71	46,497.00
Timothy Plan	93	-	795.00	21	855%	72	45,961.00
Horizon Kinetics LLC	31	-	35,925.00	5	1532%	73	44,124.00
Teucrium	143	58	-1,065.00	1	2302%	74	43,577.00
TrimTabs	62	6	4,636.00	69	352%	75	43,247.00
Sprott	72	-	2,471.00	57	415%	76	40,333.00
SRN Advisors	67	-	4,145.00	80	258%	77	39,173.00
Liquid Strategies	71	-	2,681.00	64	368%	78	37,142.00
AI Marketing LLC	146	-	-1,903.00	96	165%	79	36,777.00

Distillate Capital	60	2	4,961.00	16	988%	80	35,818.00
Goldman Sachs	145	-	-1,606.00	105	16%	81	35,509.00
Howard Capital Management	70	-	2,950.00	90	196%	82	34,914.00
Redwood Investment Management	89	11	995.00	25	812%	83	33,397.00
Regents Park Funds	64	6	4,269.00	92	189%	84	32,508.00
Government of Sweden	58	-	5,132.00	4	1572%	85	31,770.00
WBI	150	-	-3,141.00	29	769%	86	31,054.00
Simplify Asset Management Inc	46	1	12,891.00	47	484%	87	29,481.00
T Rowe Price Group Inc	56	-	6,653.00	66	360%	88	26,730.00
Tuttle Tactical Management LLC	151	1	-3,472.00	138	-423%	89	25,376.00
ClearShares LLC	127	-	0.00	100	137%	90	25,129.00
Mcivy Co LLC	75	-	1,890.00	157	-2414%	91	22,905.00
Donald L Hagan LLC	57	-	5,793.00	40	604%	92	22,494.00
Intangible Capital	120	-	1.00	94	175%	93	20,025.00
Core Alternative Capital	88	11	1,002.00	30	764%	94	17,871.00
Capital Impact Advisors	116	-	66.00	158	-2458%	95	16,885.00
Cboe	59	-	5,083.00	11	1323%	96	16,390.00
State Street Global Advisors Limited	141	-	-908.00	115	N/A	97	15,237.00
Little Harbor Advisors	65	1	4,249.00	55	422%	98	15,114.00
ProcureAM	110	-	269.00	146	-783%	99	12,740.00
Gadsden	85	-	1,135.00	84	240%	100	12,117.00
Syntax Advisors	74	-	2,008.00	36	687%	101	11,822.00
TrueMark Investments	73	-	2,435.00	128	-83%	102	11,816.00
Arrow Funds	119	-	56.00	45	503%	103	11,366.00
AGF	132	-	-24.00	147	-786%	104	10,636.00
Wahed	76	-	1,873.00	82	247%	105	10,524.00
Exponential ETFs	106	13	377.00	18	935%	106	9,753.00
Kingsview Partners LLC	68	-	3,765.00	118	N/A	107	9,676.00
Wainwright Inc	128	-	0.00	116	N/A	108	7,959.00
Pettee Investors	101	-	502.00	8	1408%	109	7,324.00
Humankind USA LLC	84	-	1,198.00	117	N/A	110	6,914.00
Advisors Asset Management	80	17	1,434.00	13	1176%	111	6,574.00
Groupe BPCE	92	-	896.00	46	503%	112	6,498.00
Change Finance	79	9	1,674.00	56	418%	113	6,306.00
iM Square SAS	96	-	670.00	78	262%	114	6,206.00
Metaurus Advisors	109	13	294.00	86	233%	115	6,176.00
Pacific Life	131	-	-11.00	102	66%	116	5,731.00
Impact Shares	82	9	1,332.00	58	400%	117	5,698.00
Guinness Atkinson Asset Management	97	-	664.00	135	-339%	118	5,234.00
Beyond Investing	91	-	923.00	85	237%	119	5,153.00
Absolute Investment Advisers LLC	98	-	646.00	33	735%	120	4,951.00
Roundhill Financial LLC	86	37	1,033.00	7	1434%	121	4,889.00
Toews Corp	135	14	-125.00	108	10%	122	4,535.00
Gotham Asset Management Holdings	66	6	4,184.00	31	761%	123	4,484.00
Esoterica	107	-	372.00	153	-1761%	124	4,374.00
Pyxis	139	16	-650.00	106	12%	125	4,359.00
Infusive Asset Management	129	-	0.00	123	-10%	126	4,313.00
Emles Advisors LLC	149	-	-2,720.00	87	225%	127	4,235.00
Premise	142	15	-1,027.00	68	355%	128	3,973.00
Neil Azous Revocable Trust	77	-	1,764.00	42	554%	129	3,884.00
Swan Global Investments	78	9	1,746.00	75	272%	130	3,725.00
Cabot ETF Partners LLC	105	-	448.00	152	-1590%	131	3,358.00
Red Gate Advisers LLC	102	-	501.00	119	N/A	132	3,319.00
Acquirers Funds	113	-	127.00	14	1042%	133	3,111.00
AlphaMark Advisors LLC	123	16	0.00	73	299%	134	2,592.00
Inverdale Capital Management LLC	81	8	1,421.00	17	967%	135	2,291.00
MCCM Group LLC	138	-	-564.00	160	-3251%	136	2,280.00
Alger Group Holdings LLC	94	-	742.00	120	N/A	137	2,084.00
2nd Vote Value Investments Inc	83	9	1,292.00	15	994%	138	1,943.00
WisdomTree Investments Inc	95	-	733.00	154	-1856%	139	1,668.00
Changebridge Capital LLC	103	-	469.00	132	-241%	140	1,597.00
The Leuthold Group LLC	115	-	72.00	83	243%	141	1,506.00
Rayliant Investment Research	100	10	609.00	149	-1059%	142	1,380.00
GAMCO Investors Inc	111	13	266.00	43	522%	143	1,271.00
Counterpoint Mutual Funds LLC	133	13	-60.00	104	28%	144	1,145.00
Point Bridge Capital	134	13	-83.00	3	1674%	145	1,123.00
EquBot	112	15	162.00	140	-513%	146	988.00
Mairs & Power Inc	90	-	975.00	121	N/A	147	983.00
Whitford Asset Management	99	-	620.00	19	908%	148	973.00
Ridgeline Research LLC	104	13	458.00	35	700%	149	947.00
New Age Alpha Advisors LLC	108	13	350.00	39	621%	150	656.00
Water Island Capital Partners LP	130	-	0.00	76	269%	151	650.00
Global Beta Advisors	114	-	110.00	26	781%	152	509.00
ProShares	136	17	-244.00	155	-2330%	153	446.00
Reflection Asset Management LLC	118	16	59.00	24	817%	154	329.00
Wilshire Phoenix Funds LLC	124	17	0.00	112	N/A	155	184.00
ASYMmetric ETFs	125	17	0.00	113	N/A	156	160.00
Democracy Investment Management LLC	117	-	64.00	122	N/A	157	132.00
Morgan Stanley	121	16	0.00	110	N/A	158	0.00
Innovator Management	122	92	0.00	111	N/A	159	0.00
Alternative Access Funds LLC	126	-	0.00	114	N/A	160	0.00

Source: ETF Database (2021a)

Appendix 2 Searched funds on different databases

ETFs	Website	Search
ACES	Etf.com	Renewable energy
CNRG	Etf.com	Renewable energy
CTEX	Etf.com	Renewable energy
FAN	Etf.com	Renewable energy
FRNW	Etf.com	Renewable energy
ICLN	Etf.com	Renewable energy
KLNE	Etf.com	Renewable energy
PBD	Etf.com	Renewable energy
PBW	Etf.com	Renewable energy
QCLN	Etf.com	Renewable energy
RAYS	Etf.com	Renewable energy
RNRG	Etf.com	Renewable energy
SHFT	Etf.com	Renewable energy
SOLR	Etf.com	Renewable energy
SULR	Etf.com	Renewable energy
TAN	Etf.com	Renewable energy
VCLN	Etf.com	Renewable energy
WNDY	Etf.com	Renewable energy
ACES	EtfDatabase	Alternative energy
BNE	EtfDatabase	Alternative energy
CLMA	EtfDatabase	Alternative energy
CNRG	EtfDatabase	Alternative energy
CTEC	EtfDatabase	Alternative energy
ERTH	EtfDatabase	Alternative energy
FAN	EtfDatabase	Alternative energy
GRID	EtfDatabase	Alternative energy
ICLN	EtfDatabase	Alternative energy
NLR	EtfDatabase	Alternative energy
PBD	EtfDatabase	Alternative energy
QCLN	EtfDatabase	Alternative energy
RNRG	EtfDatabase	Alternative energy
SHFT	EtfDatabase	Alternative energy
TAN	EtfDatabase	Alternative energy
BATG	justetf	Battery technology
CHRG	justetf	Battery technology
LIT	justetf	Battery technology
CGW	poems.com.sg	Water
EBLU	poems.com.sg	Water
FIW	poems.com.sg	Water
PHO	poems.com.sg	Water
PIO	poems.com.sg	Water
BATT	Seeking alpha	Battery
LIT	Seeking alpha	Battery
WBAT	Seeking alpha	Battery

Source: Self-elaboration

Appendix 3 Single iteration for the Monte Carlo Simulation

Simple Future Value	$ 234,432.78
Future value - contrib.	$ 162,432.78

Year	Espected Return	Espected FV		
1	-3.0%	$ 3,370.38	=+NORMINV(RAND();$E$9;$E$10)	=+$E$7*(1+D18)+E8
2	2.8%	$ 5,863.09		=+E18*(1+D19)+$E$8
3	0.9%	$ 8,316.71		
4	8.1%	$ 11,391.19		
5	5.7%	$ 14,442.96		
6	0.2%	$ 16,865.90		
7	19.7%	$ 22,590.85		
8	-10.6%	$ 22,591.34		
9	3.7%	$ 25,816.02		
10	8.2%	$ 30,329.85		
11	5.0%	$ 34,233.23		
12	19.1%	$ 43,186.40		
13	8.0%	$ 49,020.54		
14	13.6%	$ 58,080.01		
15	5.7%	$ 63,800.17		
16	6.1%	$ 70,122.85		
17	0.8%	$ 73,066.41		
18	25.6%	$ 94,207.24		
19	17.8%	$ 113,415.27		
20	2.6%	$ 118,753.17		
21	1.6%	$ 122,994.16		
22	13.2%	$ 141,634.32		
23	-20.4%	$ 115,184.73		
24	14.2%	$ 133,890.60		
25	4.8%	$ 142,705.43		
26	23.4%	$ 178,542.05		
27	11.3%	$ 201,089.12		
28	6.8%	$ 217,144.22		
29	1.4%	$ 222,571.09		
30	4.3%	$ 234,432.78		

Source: Self-elaboration

Appendix 4 Comparision of future median and future average prices for the MSCI World Index on early and last years

	Year 1	Year 2	Year 3	Year 4																							Year 27	Year 28	Year 29	Year 30
Average (A)	$ 3,493.40	$ 6,213.81	$ 9,032.97	$ 12,253.73	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	$ 231,552.36	$ 253,076.04	$ 279,018.07	$ 307,438.64
Median	$ 3,490.64	$ 6,192.41	$ 8,984.06	$ 12,239.17	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	$ 207,517.52	$ 230,298.35	$ 256,665.22	$ 280,156.18

Source: Self-elaboration

Appendix 5 Link to access the Monte Carlo Simulation on Excel

The Excel document that constitutes the basis of this thesis can be found in https://docs.google.com/spreadsheets/d/1RHFrrOUUAdlTgaer8iwLVZPk-wiouP-n/edit?usp=sharing&ouid=101547868267602363646&rtpof=true&sd=true and anyone can access this link, including the download of the file.