UCD Michael Smurfit
Graduate Business School

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# FIN41910 - GREEN DATA SCIENCE

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## A report
## on
## Portfolio Decarbonisation

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# 1. Executive Summary

The transition towards sustainable investing in a low-carbon economy is demonstrated through portfolio decarbonisation. This report utilises Python's data analysis and financial optimisation techniques to comprehensively analyse 100 firms from the Russell 3000 Index and reduce a portfolio's carbon footprint by altering investment allocations.

Three different reduction targets (50%, 25%, and 10%) were examined to identify an optimal balance between environmental responsibility and financial performance. The report provides a comprehensive portfolio performance evaluation by comparing key metrics such as carbon performance, Sharpe ratio, expected returns, volatility, and the number of companies. Additionally, Environmental, Social, and Governance (ESG) scores across portfolios were analysed to illustrate the potential for sustainable investing in portfolio management.

The report concludes with an in-depth examination of a selected decarbonised portfolio, analysing its sector-wise composition and contribution to ESG performance. This exploration aims to highlight the benefits, challenges, and potential areas for improvement in sustainable investing.

# 2. Research Purpose

Sustainable investing reduces greenhouse gas emissions by decarbonising portfolios for a low-carbon economy. By doing so, we can mitigate climate risks, identify economic leaders and promote responsible environmental investing.

This report examines portfolio decarbonisation using Python, showcasing its capabilities in data analysis and financial optimisation implementation. We analyse the decarbonisation strategies of 100 firms in the Russell 3000 Index, providing a sector distribution overview and highlighting carbon metrics for the decarbonisation process.

Our study examines the optimal level of carbon reduction (50%, 25%, and 10%) to help investors manage carbon risk and improve portfolio resilience against climate change [1]. To evaluate portfolio performance, we compare key statistics, including carbon performance, Sharpe ratio, expected returns, volatility, and the number of companies. In addition, we conduct an analysis of ESG scores across portfolios, presenting a more rounded perspective on sustainability.

The report examines portfolio composition across sectors and industries, focusing on the ESG performance of a decarbonised portfolio. The analysis highlights decarbonisation's potential in portfolio management and its implications for sustainable finance.

The analysis provides an understanding of sustainable investing and its benefits and challenges.

# 3. Research Design

## 3.1 Sampling Method

We randomly selected 100 firms from the Russell 3000 constituents list to ensure a balanced representation of each sector. The get_random_tickers function was used to perform the random selection. The selection of tickers was kept completely random, without any restrictive randomisation within sectors, which ensured that each sector had a representation and the overall dataset was a diverse and balanced sample, with ten firms from the Information Technology sector, twenty four from Industrials and likewise.

## 3.2 Carbon Metric

We calculated a company's carbon emissions using a "Carbon Intensity" measure. This new feature involved adding up the "Scope 1" and "Scope 2 Location" emissions and then dividing them by the company's "Revenue" value (in $mn).

Companies are responsible for their greenhouse gas emissions (Scope 1) and emissions generated by the electricity purchased (Scope 2). The Carbon Intensity target is gaining popularity and is an essential tool for assessing environmental performance. It allows

comparing environmental performance across companies and industries and can be used to track a company's progress in reducing its carbon emissions [2].

## 3.3 Optimisation Strategy

The optimisation strategy in our portfolio decarbonisation problem consists of two different portfolio allocation methodologies: Market Cap portfolio, and Mean-Variance Efficient Portfolio. Decarbonisation is applied for both these methods.

The function "market_cap_portfolio" simulates a benchmark portfolio by assigning weights to stocks based on their market capitalisations. It takes in the cleaned data frame "df_final" containing financial and environmental data of 100 stocks, expected returns for all stocks "mu", the covariance matrix of stock returns "S", and a risk-free rate:

1. The function uses the "get_benchmark_portfolio" method to calculate the portfolio weights based on the market capitalisation of each stock and the expected returns and ESG scores of each stock in the portfolio, weighted by their respective portfolio weights.
2. The "get_portfolio_performance" method calculates the portfolio's performance metrics, such as annualised expected return, volatility, Sharpe Ratio, and the number of companies in the portfolio. These metrics are printed using the "print_portfolio_stats" method.
3. The "get_portfolio_scores" method computes the portfolio's ESG scores, which are then printed using the "print_portfolio_scores" method.

The function returns a tuple comprising the portfolio weights, performance metrics, and ESG scores.

Moreover, the "decarbonised_portfolio" creates a portfolio that meets decarbonisation constraints. It takes various parameters, including an initial carbon intensity, a target reduction rate, an optimiser instance, a data frame of stock prices, expected returns, a covariance matrix, the carbon intensity of each stock, a data frame containing all financial and environmental data of the stocks, and the weights of the benchmark portfolio. The method determines a target carbon intensity by multiplying the total initial carbon intensity with the intensity reduction rate. It creates an "EfficientFrontier" object and adds constraints to ensure that the portfolio's carbon intensity equals the target carbon intensity and that the sum of portfolio weights equals 1. If the flag "is_sector_balance_portfolio" is set to True, it adds sector balance constraints. The method selects a decarbonisation objective function and computes the optimal weights using the "clean_weights" method. This produces the decarbonised portfolio weights. The function adds the portfolio performance and ESG scores using "get_portfolio_performance" and "get_portfolio_scores", respectively. These metrics are printed out and returned along with the portfolio weights.

The function "mean_variance_efficient_portfolio" maximises the Sharpe ratio while considering decarbonisation constraints by taking parameters such as expected returns, covariance matrix, processed data, benchmark weights, initial portfolio carbon intensity, the carbon intensity of each stock, a flag for decarbonisation constraints, and a risk-free rate. An "EfficientFrontier" object is created, and depending on the "is_decarbonised" flag, either a constraint ensuring that the portfolio's carbon intensity equals 50% of the initial carbon intensity or limits the weights to 0 and 1 are added. In both cases, the sum of portfolio weights is constrained to be 1. The "max_sharpe" method is called to get the portfolio weights that maximise the Sharpe ratio. The optimal weights are then cleaned to compute the portfolio performance and ESG scores, which are printed and returned along with the portfolio weights.

Using these optimisation strategies, we can form portfolios that maximise financial returns and consider carbon intensity and ESG factors, thereby allowing us to build portfolios that align with sustainable investment strategies.

# 4. Findings

This section presents the performance and characteristics of several constructed portfolios, including our market cap-based portfolio. We begin with the basic descriptive statistics of the market cap-based portfolio derived from our Python code:

Descriptive Statistics for Market Cap-Based Portfolio:

- Mean: 32725
- Standard Deviation: 77066
- Minimum: 159
- Maximum: 572370
- Median: 6577

These statistics show the distribution of market capitalisation in our portfolio, highlighting the vast range of company sizes it comprises. In particular, the mean market cap is significantly higher than the median, indicating the presence of companies with exceptionally high market caps and skewed dataset.

In Table 1, we used ESG statistics to measure the quality of firms' environmental, social, and governance practices in our portfolios. The Benchmark Market Cap-Based Portfolio has the highest Mean Annual Emission, significantly reduced in all decarbonised portfolios (Portfolio1 and Portfolio4), targeting a 50% reduction. It also presents the highest Average ESG Score, with Decarbonised Portfolio 3 coming closest. For the individual ESG components, the Benchmark portfolio has the highest Average Governance Score, but the others follow closely. The Mean-Variance Portfolio is the only one surpassing the Benchmark for the Average Environment Score. The Benchmark also has the highest Average Social Score, significantly higher than the Mean-Variance and Decarbonised Mean-Variance portfolios.

| Portfolio | Mean Annual Emission | Avg ESG Score | Avg Environment Score | Avg Governance Score | Avg Social Score |
|---|---|---|---|---|---|
| **Benchmark Market Cap Based Portfolio** | 0.065771 | 57.857761 | 46.704921 | 91.652791 | 35.082661 |
| **Decarbonised Portfolio1 (50% reduction)** | 0.032901 | 56.904097 | 45.307110 | 91.363939 | 33.905919 |
| **Decarbonised Portfolio2 (25% reduction)** | 0.049331 | 56.813988 | 45.325824 | 91.191688 | 33.789379 |
| **Decarbonised Portfolio3 (10% reduction)** | 0.059199 | 56.882924 | 45.491334 | 91.241436 | 33.780923 |
| **Decarbonised Portfolio4 (50%, Sector-Balanced)** | 0.032881 | 51.765397 | 36.028721 | 88.555459 | 30.570569 |
| **Mean-Variance Portfolio** | 0.024867 | 53.773857 | 36.458705 | 86.010037 | 38.732090 |
| **Decarbonised Mean-Variance Portfolio** | 0.032885 | 53.929824 | 36.757372 | 86.041662 | 38.870098 |

Table 1: ESG Performance

Moreover, we evaluated our portfolio performance in Table 2 using Sharpe Ratio, Expected Returns, and Volatility. The Benchmark Market Cap-Based Portfolio has moderate returns but does not outperform the Mean-Variance and Decarbonised Mean-Variance portfolios. The decarbonised portfolios have lower returns, with the 50% sector-balanced decarbonised portfolio performing the lowest.

| Portfolio | Companies Invested | Sharpe Ratio | Annual ExpReturn | Monthly ExpReturn | Annual Volatility | Monthly Volatility |
|---|---|---|---|---|---|---|
| **Benchmark Market Cap Based Portfolio** | 100 | 0.731356 | 13.542125 | 1.128510 | 18.379724 | 5.305769 |
| **Decarbonised Portfolio1 (50% reduction)** | 100 | 0.699307 | 12.954046 | 1.079504 | 18.381124 | 5.306173 |
| **Decarbonised Portfolio2 (25% reduction)** | 100 | 0.688423 | 12.741583 | 1.061799 | 18.363101 | 5.300971 |
| **Decarbonised Portfolio3 (10% reduction)** | 100 | 0.687081 | 12.698378 | 1.058198 | 18.336082 | 5.293171 |
| **Decarbonised Portfolio4 (50%, Sector-Balance** | 100 | 0.254284 | 5.070163 | 0.422514 | 19.545733 | 5.642367 |
| **Mean-Variance Portfolio** | 100 | 1.340716 | 20.412717 | 1.701060 | 15.150645 | 4.373614 |
| **Decarbonised Mean-Variance Portfolio** | 100 | 1.339933 | 20.326301 | 1.693858 | 15.095009 | 4.357554 |

Table 2: Portfolio Analysis

Furthermore, Table 3 shows that the Benchmark portfolio has the highest Energy and Information Technology weights in the sector-wise distribution. However, MV_Portfolio has no allocation to Energy and Industrials.

Let us examine Decarbonized Portfolio 1. It reduces allocations to Utilities, IT, and Energy sectors compared to the Benchmark portfolio but increases the allocation to Consumer Staples, Consumer Discretionary, and Real Estate sectors. This balanced approach ensures a well-diversified investment.

| GICS Sector | Benchmark | DC_1 | DC_2 | DC_3 | DC_4 (Sector Balance) | Mean Variance | DC_5 (MTP) |
|---|---|---|---|---|---|---|---|
| **Communication Services** | 0.153113 | 0.15177 | 0.14487 | 0.14636 | 0.05220 | 0.07891 | 0.07910 |
| **Consumer Discretionary** | 0.094371 | 0.10087 | 0.09752 | 0.09612 | 0.13641 | 0.21705 | 0.21426 |
| **Consumer Staples** | 0.153006 | 0.16027 | 0.15431 | 0.15549 | 0.07984 | 0.09108 | 0.09006 |
| **Energy** | 0.022630 | 0.01093 | 0.01302 | 0.01294 | 0.03757 | 0.00000 | 0.00000 |
| **Financials** | 0.053207 | 0.04842 | 0.04531 | 0.04344 | 0.07384 | 0.06170 | 0.05948 |
| **Health Care** | 0.018256 | 0.02622 | 0.02816 | 0.02757 | 0.07345 | 0.13174 | 0.13092 |
| **Industrials** | 0.091181 | 0.08570 | 0.09290 | 0.09205 | 0.23780 | 0.00000 | 0.00000 |
| **Information Technology** | 0.326212 | 0.31888 | 0.31254 | 0.31327 | 0.10588 | 0.23564 | 0.23500 |
| **Materials** | 0.025482 | 0.02381 | 0.02936 | 0.02922 | 0.05547 | 0.10391 | 0.10762 |
| **Real Estate** | 0.049309 | 0.06411 | 0.06802 | 0.06670 | 0.11458 | 0.07996 | 0.08119 |
| **Utilities** | 0.013232 | 0.00910 | 0.01402 | 0.01683 | 0.03300 | 0.00000 | 0.00237 |

Table 3: Sector Composition Analysis

# 5. Conclusion

Using Python's data analysis and optimisation techniques, we decarbonised portfolios of 100 companies from the Russell 3000 Index. Our methodology balanced environmental responsibility and financial performance by examining three carbon reduction targets. Key metrics, such as carbon performance and ESG scores, highlight the value of sustainable investing in identifying economic leaders and mitigating climate-related risks. Despite challenges, the potential rewards are substantial.

# 6. References


1. How to create a roadmap to decarbonising your asset portfolio | Wood (woodplc.com)
2. GHG Protocol: Scope 2 Emissions Explained - Green Business Bureau