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MATEUS VILELA PELOSO VASCONCELOS

Evaluating the Efficiency of ESG Actions in the German Industrial Machinery and Equipment Sector: A DEA Approach

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Main Supervisor: Associate Professor Daisy Aparecida do Nascimento Rebelatto.

Second Supervisor: Ícaro Guilherme Félix da Cunha

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Comissão Julgadora	**Resultado**
Professora Associada Daisy Aparecida do Nascimento Rebelatto (orientadora)	Aprovado
Instituição: EESC - SEP	
Professora Doutora no IFMG Congonhas Renata Veloso Santos Policarpo	Aprovado
Instituição: EESC - SEP	
Pesquisador Ícaro Guilherme Félix da Cunha	Aprovado
Instituição: EESC - SEP	

Presidente da Banca: **Professora Associada Daisy Aparecida do Nascimento Rebelatto**

ABSTRACT

The principles of Environmental, Social and Governance (ESG) are recognized as key strategic actions for progression among the main global stakeholders. In particular, the Industrial Machinery and Equipment (M&E) sector is experiencing significant global transformation, traditionally linked with resource-intensive processes and environmental impact, companies in this sector are now re-evaluating their operational models to align with ESG standards. In this context, it is natural to ask: Which companies in the sector of Industrial Machinery & Equipment are better employing their financial resources to improve their ESG score? In particular, this study aims to evaluate the efficiency of transforming financial resources into environmental, social and governance (ESG) results by German companies in the Industrial Machinery and Equipment sector from 2018 to 2022, through Data Envelopment Analysis (DEA). The focus on the Machinery and Equipment sector in Germany is because it is ranked as the second-largest sector in the country's economy. Applying the resource-based view (RBV) entrepreneurship theory to ESG principles in the modern economy, we use data collected from the Refinitiv Platform and apply the DEA method to arrive at a rank of the most efficient German companies in converting financial resources into ESG achievements in the M&E sector. Based on the application of the DEA method we identify the top ranked companies in our study, and we make a qualitative benchmark analysis of these companies and analyze their strategic effectiveness through the Porter's Five Forces framework. Our results highlight Nordex SE and SGL Carbon as competitive benchmarks for the M&E sector, and Siemens AG as a functional benchmark for the whole industry.

Keywords: DEA; ESG; Machinery and Equipment; ROE; Germany

RESUMO

Os princípios de Environmental, Social e Governance (ESG) são reconhecidos como ações estratégicas fundamentais para o progresso entre os principais stakeholders globais. Em particular, o setor de Máquinas e Equipamentos Industriais (M&E) está passando por uma transformação global significativa. Tradicionalmente ligado a processos intensivos em recursos e impacto ambiental, as empresas deste setor estão agora reavaliando seus modelos operacionais para se alinhar aos padrões ESG. Nesse contexto, é natural perguntar: Quais empresas do setor de Máquinas e Equipamentos Industriais estão melhor empregando seus recursos financeiros para melhorar sua pontuação ESG? Em particular, este estudo tem como objetivo avaliar a eficiência em transformar recursos financeiros em resultados ambientais, sociais e de governança (ESG) por empresas alemãs no setor de Máquinas e Equipamentos Industriais de 2018 a 2022, por meio da Análise Envoltória de Dados (DEA). O foco no setor de Máquinas e Equipamentos na Alemanha se deve ao fato de ser classificado como o segundo maior setor da economia do país. Aplicando a teoria de empreendedorismo baseada em recursos aos princípios ESG na economia moderna, utilizamos dados coletados da Plataforma Refinitiv e aplicamos o método DEA para chegar a um ranking das empresas alemãs mais eficientes em converter recursos financeiros em realizações ESG no setor de M&E. Com base na aplicação do método DEA, identificamos as empresas mais bem classificadas em nosso estudo e fazemos uma análise de benchmark qualitativo dessas empresas, analisando sua eficácia estratégica por meio da estrutura das Cinco Forças de Porter. Nossos resultados destacam a Nordex SE e a SGL Carbon como benchmarks competitivos para o setor de M&E, e a Siemens AG como um benchmark funcional para toda a indústria.

Palavras-chave: DEA; ESG; Máquinas e Equipamentos Industriais; ROE; Alemanha

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1. INTRODUCTION

Since the beginning of the new millennium, the world has experienced several macroeconomic and political crises, such as the 2008 financial crisis, the climate emergence, the COVID-19 pandemic, and the Russia-Ukraine war. As a result of these occurrences, it is evident that a fundamental alteration in the global economic paradigm is required (Becchetti et al., 2022; Cheema-Fox et al., 2021a). Thus, in order to speed up this transition, it is important to establish a strong collaboration among the main global stakeholders.

For that, the principles of Environmental, Social, and Governance (ESG) are recognized as key strategic actions for progression. These principles have a structural influence on corporate strategies, shaping the trajectories of financial lending and investment decisions (Cheema-Fox et al., 2021b; Lins et al., 2017). Moreover, the sense of responsibility and accountability between consumers and investor is greatly fostered, guiding, and influencing public and private choices (Alda, 2019).

The ESG principles emerge from the necessity to reward companies proficient in generating value, returns, and impacts beyond economic terms. Thus, encompassing dimensions of social and environmental sustainability (Hajian & Kashani, 2021). Consequently, this maintains equilibrium in the triple bottom-line approach (profit, planet, and people).

The achievement of this goal is made feasible through the application and use of ESG ratings and indexes. This empowers investors and managers to evaluate and report on companies, not exclusively relying on financial metrics, but also incorporating social and environmental parameters. The ESG reports also enable the identification of ESG controversies, such as the use of nuclear energy and the production and the sale of guns.

Furthermore, some research has shown that companies that comply with ESG principals, and have better ESG ratings, demonstrate better financial performances when compared to companies that do not comply with these principles (Kocmanová & Dočekalová, 2012; Koroleva et al., 2020a). Hence, the number of investors and investment funds that use ESG ratings and principals as a fundamental part of their investment analysis has grown in the last decade (GSIA, 2018).

1.1. Research relevance

One economic sector that is undergoing a notable evolution on the global stage driven by the Environmental, Social, and Governance (ESG) mindset change is the Industrial Machinery and Equipment (M&E) sector. Historically associated with resource-intensive processes and environmental impact, companies within this sector are rethinking their operational paradigms to be in accordance with ESG principles (Görlitz, 2022).

Interesting initiatives encompass energy-efficient technologies and conscientious waste management. Moreover, worth mentioning is the growing awareness of the social and governance aspects, with an increased emphasis on fostering a safe and inclusive workplace, as well as transparent and ethical business practices (Baccaro & Benassi, 2017; Görlitz, 2022).

Recently, China has emerged as a formidable competitor on the M&E global stage, challenging established players (Vu, 2015). For many years, the European, and North American companies being known for their quality aspect, while the Asian counterparts for their price aggressiveness. However, increasingly the new market enterprises have matched the traditional ones in terms of quality, which has made the M&E sector more price-sensitive (Baccaro & Benassi, 2017).

However, due to ESG mindset change, companies are no longer evaluated solely on price and quality. Environmental, Social, and Governance (ESG) factors have gained prominence, compelling companies to adopt more sustainable and ethical practices (Aich et al., 2021). This shift has influenced consumer preferences and investment strategies, urging M&E firms to integrate ESG principles into their operations. Firms that excel in these areas are now considered more attractive to investors and consumers alike, driving a need for comprehensive evaluation of their ESG initiatives.

Thus, the necessity to evaluate who the leading firms in ESG principles are – from the M&E sector – has emerged, to enumerate the strategic initiatives undertaken by these corporations to improve their value-creation efforts, and what insights can be learned from them. Consequently, this research has chosen to study all the publicly listed companies from the M&E sector in Germany.

The choice of the German market was made for two main reasons. Firstly, Germany stands as the preeminent economy in Europe, mainly attributable to its

longstanding manufacturing tradition, which is the core of its economy (Yu, 2023). Therefore, studying a nation that leads the world in the Industrial Machinery & Equipment sector allows this research to evaluate what is considered as the state of the art in the industry (Stefan, 2012).

Secondly, the adoption of Environmental, Social, and Governance (ESG) ratings and analysis in Germany follows European sustainability principles and legislative frameworks, which provides this research with reliable and accurate data. Moreover, the ESG ratings and data accessible for the German market through the Refinitiv platform encompass considerable historical records from all the companies of the Industrial Machinery & Equipment sector, thereby enabling the continuation of this research.

The theoretical background of this part is the resource-based view (RBV) of strategic management theory (Barney, 1991; Newbert, 2007). The RBV assumes that valuable and rare firms' resources can culminate in superior value-creating strategies when they are empowered in the correct way, and not all the companies in a sector manage to achieve equivalent outcomes. This better use of resources creates a competitive advantage for the company.

Recognizing ESG factors as difficult-to-imitate, valuable, and rare resources (Koroleva et al., 2020a), and considering that DEA identifies the most efficient companies in deploying their resources towards improving their E/S/G ratings, this study aims to identify the competitive advantages of these companies, as well as listing the Firm's Resources, and the Value-creating strategies being employed.

The findings of this project may be used and incorporated into management practices. Therefore, managers and stakeholders can have additional information to improve their companies' business performance and efficiency, as well as build new guidelines for implementing ESG practices based on benchmarks.

Furthermore, this research contributes to the literature of Data envelopment analysis and the Resource-based view of entrepreneurship theory.

1.2. Research problem and objectives.

This study's problem can be formulated as follows: **Which companies in the sector of Industrial Machinery & Equipment in Germany are better employing their financial resources to improve their ESG score?**

To answer the research problem, this study aims to evaluate the efficiency of transforming financial resources into environmental, social and governance (ESG) results by German companies in the Industrial Machinery and Equipment sector from 2018 to 2022, through Data Envelopment Analysis (DEA).

Employing DEA as the chosen statistical analysis methodology, and exporting data from Refinitiv Eikon database, this research correlates the companies' financial performance and indicators with ESG data. Therefore, from a total of sixty-eight companies in Germany within the Industrial Machinery & Equipment sector, an anticipated outcome is a ranking of the most efficient companies in converting financial resources into ESG achievements.

1.3. Research Structure

In addition to the introductory chapter, this work contains four other chapters. Chapter 2 reviews the preliminary concepts for our study. First, we introduce the sector of Machinery and Equipment (M&E) in Germany, accessing its key role in the country's economy. Then, we present the resource-based view approach for strategic management of a company and introduce the ESG's fundamental principles. Chapter 3 covers the methods used, which employ the Data Envelopment Analysis (DEA) tool for evaluating the efficiency of ESG actions undertaken by the companies under scrutiny. In Chapter 4, we describe our results regarding the DEA calculations and proceed to a more in-depth benchmark analysis with the top-ranked companies and their impact on the sector. Finally, we conclude with some final remarks.

2. LITERATURE REVIEW

In this chapter, we will make a brief review of some preliminary concepts for our study. First in Section 2.1, we make an overview of the sector of Industrial Machinery & Equipment in Germany, and then, in Section 2.2, we introduce the preliminary concept in management theory of the resource-based view (RBV) which we employ in our study. In Section 2.3 we introduce the fundamental principles of the ESG factors and in Section 2.4 we introduce Porter's Five Forces framework to analyze the effectiveness of a company's strategic planning.

2.1. Industrial Machinery & Equipment in Germany

According to Görlitz (2022), the Machinery and Equipment sector, ranked as the second-largest sector in Germany's economy, played a vital role in the country's industrial growth in 2021, and on a global scale, Germany contributes 16% of trade in M&E products, establishing the European nation as the main supplier ahead of the US and China. In the spectrum of all German public companies, the M&E sector is the second largest in Germany, with a market cap of 258 billion euros as of July 2024 (Refinitiv, 2023), only behind the Software and IT services sector. The M&E sector functions as a technological engine that makes the country a high-tech nation.

Appendix 1 presents all public traded companies constituting the sector in Germany (Refinitiv, 2023). As examples for products produced, we can list:

- Pumps and Compressors.
- Engines and turbines.
- Machine Tools.
- Power Transmission Machinery.
- Material Handling Technology.
- Air Handling Technology.
- Agricultural Machinery.
- Construction Equipment and Building Materials Machines.

The German economic model is a characteristic Coordinated Market Economy (CME) (Baccaro & Benassi, 2017), expressed by the regulation of the market through formal institutions that coordinate interactions between firms and other stakeholders,

including suppliers, customers, and employees. This sets the German economy apart from the traditional Liberal Market Economy (LME) model (Hall & Soskice, 1986).

Over the last 20 years, the Germany has transitioned from a GDP growth model pulled primarily by household income and consumption to a new one that is more export-oriented (where the growth is driven mainly by export), making it the engine of economic growth (Baccaro & Benassi, 2017). Consequently, the importance of the M&E sector is now greater than ever. A quantitative example was provided by Görlitz (2022), which indicated that more than 50 percent of German manufacturing turnover came from international markets and not the domestic market.

As challenges, the effects of China and India on manufactured exports from the G7 economies cannot be forgotten. With the growth of Asian industry and manufacturing exports, a process of deindustrialization is happening in all G7 and developed countries, with the only exception, for now, being Germany (Vu, 2015). However, other impacts were felt in the German markets that represent a threat to continuous economic growth.

Baccaro & Benassi (2017) highlight a shift in the price sensitivity of M&E products and industrial goods in general. This is attributed to the near matching of the renowned German quality standards by international competitors, who have a more competitive price. This means that the preference for German products is no longer as obvious as it was at the end of the last century. As a response, numerous firms implemented initiatives to reduce costs and regain competitive advantages. This, though, caused several problems regarding employees, unions, and other stakeholders.

German firms do not compete on cost but rather on quality (Baccaro & Benassi, 2017). This has always been the strategy and the distinguishing characteristic of German products. Thus, the cohesion of ESG principles presents an opportunity for M&E German companies to enjoy the benefits of the ESG investment mindset shift and, therefore, gain a competitive advantage over their global benchmarks.

2.2. Resource-based view

Out of all strategic management theories, the resource-based view (RBV) is one of the most well-regarded and accepted. According to the theory, the expansion of a firm is tied to the manner in which companies' resources are employed, irrespective of whether such growth came from an organic (natural growth) or inorganic (mergers and acquisitions) way (Newbert, 2007)). In other words, a business organization is a collection

of productive resources with the capacity to add potential value to a firm, thereby enabling value-creating strategies, only if they are empowered in the correct manner.

Barney (1991) defines firm resources as all assets under the control of a particular company that enable the conception of and implementation of strategies that improve its efficiency and effectiveness. The author defines what are value-creating strategies, which can derive from (i) Physical capital resources (firm's plan and equipment, geographic location, access to raw materials), (ii) Human capital resources (training, experience, relationships), or (iii) Organizational capital resources (formal planning, controlling, relationships with the environment and economy).

Hence, the performance of an enterprise or institution is directly correlated not only with its products but also with the resources integrated into the production process (Newbert, 2007). This indicates that companies that identify and acquire resources, which are critical to the development of a product or a business strategy, are likely to achieve superior results and outcomes when compared to companies that fail to do the same.

When describing his resource-based view model, Barney (1991) assumes that firms within a given industry (or group) are heterogeneous regarding the strategic resources under their control. Moreover, he emphasizes that such resources may not be perfectly mobile across firms and are difficult to imitate by other companies, thereby establishing a long-lasting heterogeneity between competitors. Companies may have competitive advantages between each other that can be matchless and exclusive, fostering a sustained competitive advantage. The following table outlines key concepts and their definitions from Barney's framework.

Table 1 - Key concepts from RBV

Concept	Definition
Competitive Advantage	When it is implementing a value creating strategy, not simultaneously being implemented by any current or potential competitors.
Sustained Competitive Advantage	When it is implementing a value creating strategy not simultaneously being implemented by any current or potential competitors, and when these other firms are unable to duplicate the benefits of this strategy.
Sustained	The inability of current or potential competitors to duplicate that strategy that makes a competitive advantage sustained.

Source: Barney (1991)

When applying the RBV entrepreneurship theory to ESG principles in the modern economy, Koroleva et al., (2020) revealed that ESG factors are rare and difficult-to-imitate resources. Therefore, companies equipped with the right value-creation strategy

for ESG can achieve superior performance, thereby securing a Sustained Competitive Advantage.

Moreover, However, he also points out that not all firms possess the capacity to emulate the strategy of others; only those with the right management and financial capabilities do. Therefore, it is also possible to infer that ESG indicators are rare and difficult-to-imitate resources that lead to a Competitive Advantage.

The concepts of the resource-based view of strategic management theory will be employed upon identifying the leading German companies within the Industrial Machinery & Equipment sector. Since DEA identifies the most efficient companies in deploying their resources to improve ESG ratings, it will enable the identification of these companies' competitive advantages. Additionally, it will enumerate the firm's resources being utilized and the value-creating strategies implemented.

2.3. ESG Fundamentals

Following the ESG principals are sometimes misguided by some misleading biases which suggest that it only contains actions to mitigate polluting emissions. Contrary to such misconception, ESG initiatives provides a guideline encompassing all stages in the value chain, which extends from cost reduction to securing a Sustained Competitive Advantage (Koroleva et al., 2020a).

The Environmental dimension is designed to examine a company's environmental stewardship (Sahut & Pasquini-Descomps, 2015), i.e., the responsible use and protection of the environment through conservation and sustainable practices, including measures of a company’s water usage, energy use, waste, pollution, natural resource conservation, and even treatment of animals. It also evaluates the environmental risks a company might face and how it manages those risks. For example, a common environmental indicator of a company is its carbon footprint, i.e., total greenhouse gas emissions produced (Guo & Yang, 2024). Corporate environmental actions can be seen in investments in renewable energy sources, such as solar or wind power, to reduce their carbon footprint.

The Social dimension looks at how a company manages its relationships with employees, suppliers, customers, and the communities where it operates (Sahut & Pasquini-Descomps, 2015). This includes issues like labor practices, diversity and inclusion, human rights, consumer protection, community engagement, among others. An example of a social action is when a company enhances diversity and inclusion programs,

including training, mentorship, and recruitment efforts, aiming to improve employee's satisfaction and retention rates, promote a more inclusive workplace culture, and enhance company reputation.

The Governance criterion deals with aspects of how the company operates, and the mechanisms by which it, and its people, are held to account (Amel-Zadeh et al., 2017). It encompasses many aspects such as the company's leadership, executive pay, audits, internal controls, and shareholder rights, including measures of board diversity and structure, executive compensation, political contributions, and bribery and corruption policies. A simple example of a governance action is when a company establishes robust internal audit system to prevent fraud and corruption to increase the trust from investors and stakeholders and achieve a better risk management in its corporate governance.

The performance of a company is strongly tied to the level of governance that it possesses (Koroleva et al., 2020a). It encompasses a broad spectrum of indicators and analysis fields, such as risk management, accounting practices, taxation disclosure, compositions of the board of directors, anti-competition practices and business ethics (Koroleva et al., 2020a).

Recently, the ESG principles have increasingly proven its influence on stocks' returns, resulting in the shift from a two-dimensional, i.e., risks versus returns, into a multidimensional setting, e.g., risks versus returns versus ESG. While studies on ESG and stock performance have traditionally used a qualitative approach, such as negative screening (Boubaker et al., 2023), there have been recent attempts to use quantitative methods to assess the ESG performance of firms and its impact on stock performance (Boubaker et al., 2023).

In particular, Koroleva et al., (2020), establishes a positive correlation between ESG factors and financial performance, indicating that companies that engage with ESG principals have higher performance indexes. In the research, through statistical methodology, it was revealed that ESG oriented companies have a 2% higher ROA and 1% higher ROE and ROIC when compared to non-ESG-oriented counterparts.

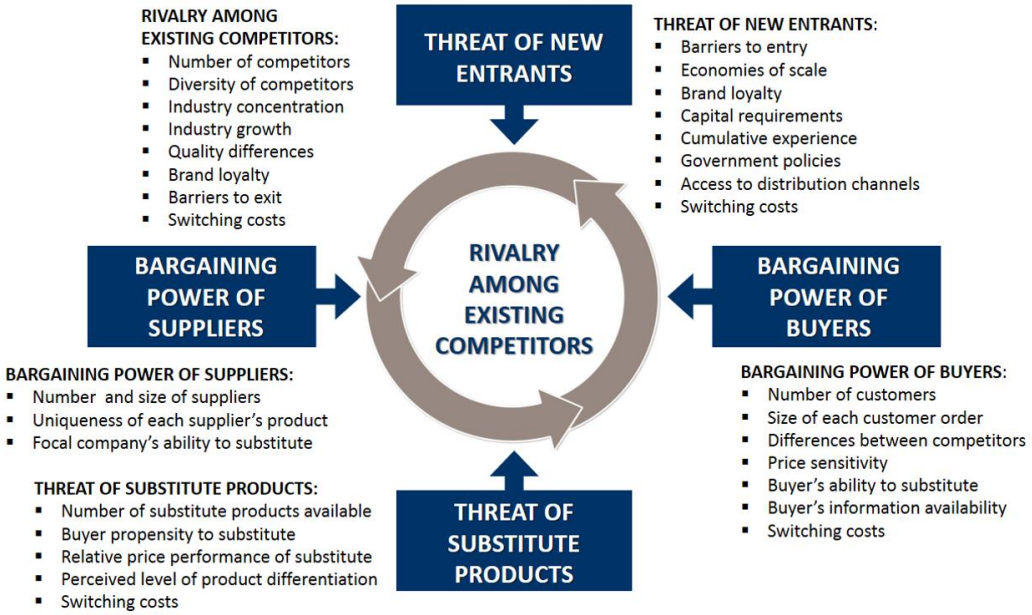
Moreover, (Pedersen et al., 2021) argued that ESG could also be included in the objective function of the optimization, in which there is a trade-off between the risk on return and ESG. In other words, if two investors have the same risk aversion but different ESG preferences, the one concerned more about ESG would choose a portfolio with

higher ESG but lower risk. In contrast, if the two have the same ESG preference, the investor with a higher risk aversion should select a high risk but low-ESG portfolio (Pedersen et al., 2021). Therefore, the ESG-frontier reflects the investment opportunities when investors care about risks, returns, and ESG simultaneously.

2.4. Porter Forces

In the field of business strategy, understanding the competitive dynamics of an industry is crucial for developing effective strategic plans. One of the most influential frameworks for analyzing industry structure and competitiveness is Porter's Five Forces, introduced Porter (1980) in his seminal work. This framework helps businesses identify the key forces that shape competition within an industry and determine its profitability. Porter's Forces model examines five specific factors given by: bargaining power of suppliers, bargaining power of buyers, threat of new entrants, threat of substitute products, and competitive rivalry. Figure 1 exhibits the framework from the Five Forces of Porter model.

Figure 1 - Five Forces of Porter model.



Source: Lars de Bruin & B2U, (2016)

On one hand, the force of bargaining power of suppliers analyzes the power that suppliers have over the pricing and quality of materials or services they provide. When suppliers are few or offer unique resources, they can exert considerable influence, potentially squeezing the margins of businesses within the industry (Porter, 1980). On the

other hand, the bargaining power of buyers evaluates the influence customers have over the pricing and quality of goods and services. When customers are concentrated or have many alternatives to choose from, they can demand lower prices or higher quality, impacting industry profitability (Porter, 1980).

The threat of new entrants assesses how easy or difficult it is for new competitors to enter the industry (Porter, 1980). Barriers to entry, such as high capital requirements, strong brand loyalty, and regulatory constraints, can protect existing players and limit new entrants, thereby affecting the competitive landscape. The threat of substitute products looks at the likelihood of customers finding alternative solutions that can replace the industry's offerings (Porter, 1980). High availability of substitutes can limit the potential for price increases and impact overall demand.

Finally, the force of competitive rivalry considers the intensity of competition among existing firms in the industry (Porter, 1980). Factors such as the number of competitors, rate of industry growth, and differentiation of products influence the degree of rivalry, which can drive down prices and reduce profitability. By analyzing these five forces, businesses can gain insights into the underlying drivers of profitability in their industry. This understanding allows firms to develop strategies that exploit favorable conditions, mitigate potential threats, and improve their competitive position.

We use Porter's Five Forces framework in our more in-depth benchmark analysis of the top-ranked companies in the German M&E sector originated from the study with the DEA dataset in Chapter 4.

3. METHOD

This study aims to evaluate the efficiency of transforming financial resources into environmental, social and governance (ESG) results by German companies in the Industrial Machinery and Equipment sector from 2018 to 2022, through Data Envelopment Analysis (DEA).

Different from other mathematical programming tools used in Management, where the objective is to evaluate a collection of possible alternatives and select the best (Planning aid to management), DEA reverses this role by employing a linear programming tool to obtain an ex post facto evaluation of relative efficiency from certain accomplishments, however they were planned or executed. DEA is, therefore, a technic for control and evaluation of past performance.

3.1. Model

First introduced by Charnes et al., (1978), DEA is a non-parametric linear programming technique with huge applicability cases, from various sectors and situations. The tool allows the researcher to evaluate the productivity efficiency of a certain object of analysis via the interaction of defined inputs and outputs from a group of homogeneous Decision-Making Units (DMUs) (Mariano & Do Nascimento Rebelatto, 2014).

Moreover, the DEA applications can be usually classified by the type of scale return and orientation. In the orientation case, the tool has three possible models: (I) Input oriented, (II) output oriented and (III) input-output oriented (Charnes et al., 1978; Santana et al., 2014). For this present study, since the global objective is to evaluate the efficiency of converting financial capabilities into ESG results, the (II) output-oriented model was chosen. This way, companies will seek to increase their output results by maintaining their inputs stable, rather than maintaining their outputs stable and decreasing their inputs.

In terms of scale return, the researcher has some choices, such as Constant Return of Scale (CRS) and Variable Return of Scale (VRS). CRS was first introduced by (Charnes et al., (1978) in the CCR model, where it guarantees that variations in the inputs will generate changes in the outputs in the same proportion, and vice versa, whereas in the VRS model, explained by (Banker et al., (1984) in the BCC model, the scale return is not necessarily proportional. The mathematical formulas for CCR and VRS can be found

in Tables 2. In this article, the modeling VRS was chosen since we seek to evaluate the efficiency of the companies, considering that the scale can be variable. Therefore, Inputs and Outputs do not change in the same proportion.

Table 2 - CRS and VRS models

Model CRS with output orientation		
	$Max\ \eta + \varepsilon * \left(\sum_{j=1}^{m} S_j^- + \sum_{i=1}^{m} S_i^+ \right)$	Objective Function
Subjected to:		
	$\sum_{k=1}^{z} \lambda_k * x_{jk} + S_j^- = x_{j0}, \quad for\ i = 1,2,\dots,m$	(R1)
	$\sum_{k=1}^{z} \lambda_k * y_{jk} - \eta * y_{j0} - S_j^+ = 0, \quad for\ i = 1,2,\dots,n$	(R2)
	$\lambda_k\ and\ \theta \geq 0, \quad for\ k = 1,2,\dots,z$	(R3)
Model VRS with output orientation		
	$Max\ \eta + \varepsilon * \left(\sum_{j=1}^{m} S_j^- + \sum_{i=1}^{m} S_i^+ \right)$	Objective Function
Subjected to:		
	$\sum_{k=1}^{z} \lambda_k * x_{jk} + S_j^- = x_{j0}, \quad for\ i = 1,2,\dots,m$	(R1)
	$\sum_{k=1}^{z} \lambda_k * y_{jk} - \eta * y_{j0} - S_j^+ = 0, \quad for\ i = 1,2,\dots,n$	(R2)
	$\sum_{k=1}^{z} \lambda_k = 1$	(R3)
	$\lambda_k\ and\ \theta \geq 0, \quad for\ k = 1,2,\dots,z$	(R4)

Source: Banker et al. (1984); Charnes et al. (1978)

Besides using the described classical approach, this study incorporates the inverted frontier approach, a distinctive analytical framework involving a sequential three-step process. Firstly, the positions of inputs and outputs are interchanged and, subsequently, the modified model is resolved. Finally, a composite index is computed, integrating assessments from both the conventional and inverted frontiers (Santana et al., 2014).

Leta et al. (2005) specify that the composite index is determined by averaging the classical frontier index (E_classical) with one minus the inverted frontier index (1 – E_inverted). To ensure that the composite index values fall between 0 and 1, they need to undergo standardization. Based on this composite index, the most proficient DMU (Decision-Making Unit) is identified as one that excels in its strengths, measured by the standard efficiency level. Simultaneously, it should not exhibit significant deficiencies in

its weaknesses, as determined by the efficiency derived from the inverted frontier subtracted from one.

The study incorporated the window analysis method, also known as the time-dependent analysis in DEA, as outlined by Cooper (2001). This approach recognizes time intervals as distinct entities, treating each company during a specific period as an individual unit. The window analysis operates as a moving average technique. The formula to determine the quantity of windows and their respective span is as follows:

$$W = k - p + 1 \quad (1)$$

$$p = \frac{k + 1}{2} \quad (2)$$

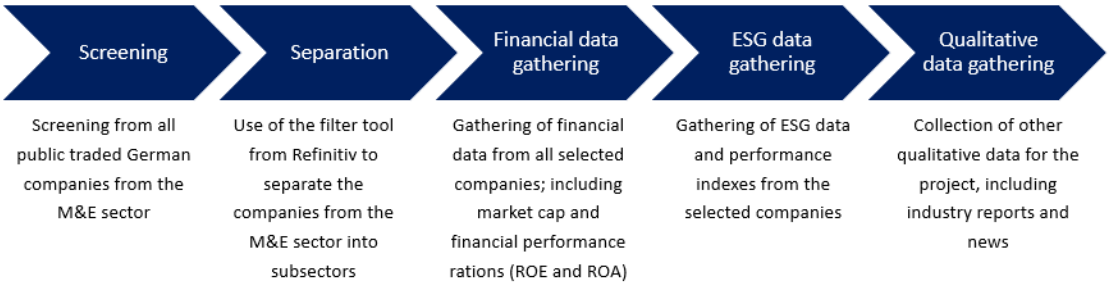
Where, W, k and p stand for number of windows, number of years and window amplitude, respectively. Considering that a five-year analysis was made (k = 5), both the amplitude (p) and number of windows (W) should be three.

3.2. Database description

This research uses the Refinitiv Eikon tool as the main data source. It was used to (i) screen all the German Companies from the M&E sector; (ii) identify the market cap of the M&E sector compared to the whole universe of German Public Companies; (iii) extract the financial performance ratios and the ESG indexes from the analyzed companies; and (iv) obtain other qualitative information for the project.

The choice for the Refinitiv platform was made based on extensive number of research that used the platform and obtained reliable results (Berg et al., 2021; Drago et al., 2019) and for having a reliable and trustworthy ESG database, indexes, and analysis (Stellner et al., 2015). The Refinitiv Eikon was used for various stages of the research and is resumed in the Figure 2.

Figure 2 - Refinitiv Eikon Uses



Source: Author

Commenting more about ESG data gathering, Refinitiv carries a full ESG database, offering the user a comprehensive and clear metric for the ESG ranking. They offer more than 400 ESG data points and ESG analytics and indexes (Refinitiv, 2024). From those, table 3 shows the worth mentioning indexes. Furthermore, Figure 3 presents the logic behind the Scores' calculation and how to interpret the data based on rankings and grades.

Table 3 - Relevant ESG indexes from Refinitiv

Indexes	**Description**
ESG Score	An overall company score based on self-reported information in the environmental, social, and corporate governance pillars.
ESG Combined Score	An overall company score based on the reported information in the environmental, social, and corporate governance pillars (ESG Score) with an ESG Controversies overlay.
ESG Controversies Score	Measures a company's exposure to environmental, social and governance controversies and negative events reflected in global media.
Environmental Pillar Score	Measures a company's impact on living and non-living natural systems, including the air, land, and water, as well as complete ecosystems. It reflects how well a company uses the best management practices to avoid environmental risks and capitalize on environmental opportunities to generate long-term shareholder value.
Social Pillar Score	Measures a company's capacity to generate trust and loyalty with its workforce, customers, and society, through its use of the best management practices. It reflects the company's reputation and the health of its license to operate, which are key factors in determining its ability to generate long-term shareholder value.
Governance Pillar Score	Measures a company's systems and processes, which ensure that its board members and executives act in the best interests of its long-term shareholders. It reflects a company's capacity, through its use of the best management practices, to direct and control its rights and responsibilities through the creation of incentives, as well as checks and balances to generate long-term shareholder value.

Source: Refinitiv, 2023

Figure 3 - ESG Score Structure

Score range	Grade	Description
0.0 <= score <= 0.083333	D -	'D' score indicates poor relative ESG performance and insufficient degree of transparency in reporting material ESG data publicly.
0.083333 < score <= 0.166666	D	
0.166666 < score <= 0.250000	D +	
0.250000 < score <= 0.333333	C -	'C' score indicates satisfactory relative ESG performance and moderate degree of transparency in reporting material ESG data publicly.
0.333333 < score <= 0.416666	C	
0.416666 < score <= 0.500000	C +	
0.500000 < score <= 0.583333	B -	'B' score indicates good relative ESG performance and above-average degree of transparency in reporting material ESG data publicly.
0.583333 < score <= 0.666666	B	
0.666666 < score <= 0.750000	B +	
0.750000 < score <= 0.833333	A -	'A' score indicates excellent relative ESG performance and high degree of transparency in reporting material ESG data publicly.
0.833333 < score <= 0.916666	A	
0.916666 < score <= 1	A +	

Source: Refinitiv (2022)

From all this available data, this study decided to use the (i) Environmental Pillar Score, (ii) Social Pillar Score and (iii) Governance Pillar Score data. The decision to analyze these scores separately, rather than using the overall ESG score, allows for a more detailed examination of each category. By doing so, we can better identify the strengths and weaknesses of each company within these specific areas. For example, a company may perform well in the Environmental and Social categories but fall short in Governance. Analyzing the aggregate ESG score alone would provide these nuances, making it harder to gain a clear understanding of each company's profile.

In the Appendix 1 a list of all German public traded companies from the Industrial Machinery and Equipment (M&E) sector is available. However, from this final group, only 18 companies (Table 4) were analyzed, due to the lack of available ESG data from the period considered for this study (2018 – 2022).

Table 4 - Public traded German Companies from the M&E sector used for this study.

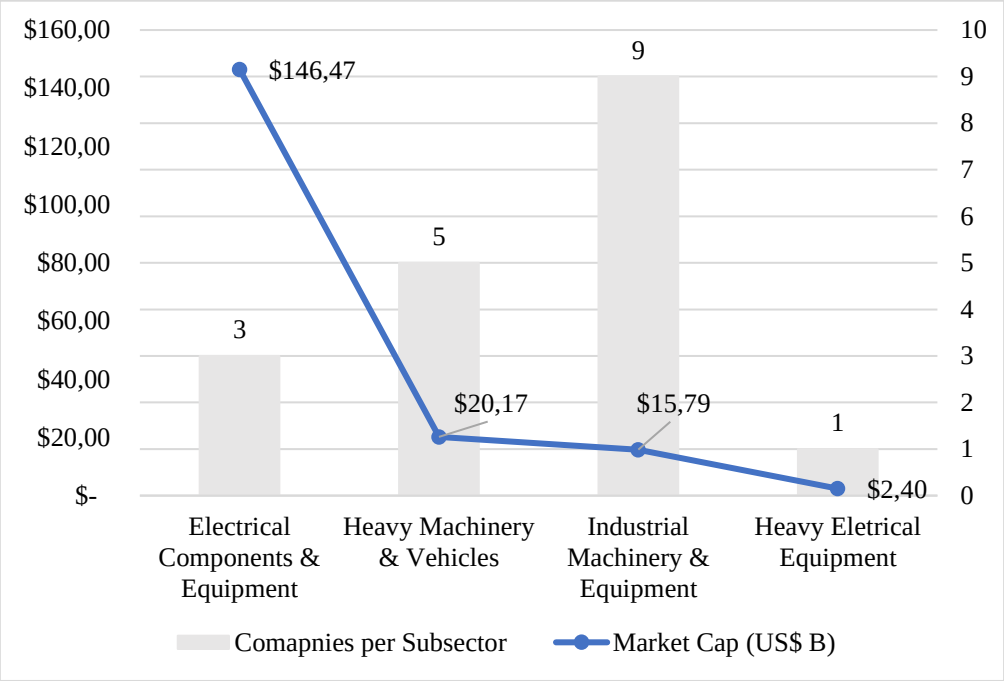
Identifier (RIC)	**Company Name**	**Subsector**	**Market Cap (USD)**
SIEGn.DE	Siemens AG	Electrical Components & Equipment	$ 144.954.826.645,21
KBX.DE	Knorr Bremse AG	Heavy Machinery & Vehicles	$ 10.291.211.042,81
G1AG.DE	GEA Group AG	Industrial Machinery & Equipment	$ 6.951.024.603,01
KGX.DE	Kion Group AG	Heavy Machinery & Vehicles	$ 6.090.910.981,72
GILG.DE	DMG Mori AG	Industrial Machinery & Equipment	$ 3.753.278.614,90
NDXG.DE	Nordex SE	Heavy Eletrical Equipment	$ 2.401.033.279,07

PV.DE	Pfeiffer Vacuum Technology AG	Industrial Machinery & Equipment	$	1.667.156.860,37
DUEG.DE	Duerr AG	Industrial Machinery & Equipment	$	1.604.049.126,00
JUNG_p.DE	Jungheinrich AG	Heavy Machinery & Vehicles	$	1.658.465.519,30
WACGn.DE	Wacker Neuson SE	Heavy Machinery & Vehicles	$	1.346.690.440,21
VAR1.DE	Varta AG	Electrical Components & Equipment	$	726.099.667,79
SGCG.DE	SGL Carbon SE	Electrical Components & Equipment	$	788.085.603,40
DEZG.DE	DEUTZ AG	Heavy Machinery & Vehicles	$	787.228.497,05
NOEJ.DE	Norma Group SE	Industrial Machinery & Equipment	$	518.842.057,59
WSUG.DE	WashTec AG	Industrial Machinery & Equipment	$	482.328.307,99
HDDG.DE	Heidelberger Druckmaschinen AG	Industrial Machinery & Equipment	$	362.148.210,77
AAGG.DE	Aumann AG	Industrial Machinery & Equipment	$	259.840.396,85
SKBG.DE	Koenig & Bauer AG	Industrial Machinery & Equipment	$	195.108.821,99

Source: Refinitiv (2023)

Graph 1 illustrates the breakdown of sub sectors based on Market Cap. The subsector “Electrical Components & Equipment” boasts the highest market capitalization, despite comprising only three components, averaging US$ 48.8 billion per company. In contrast, “Heavy Machinery & Vehicles,” “Industrial Machinery and Equipment” and “Heavy Electrical Equipment” exhibit lower market capitalizations of US$ 4.0 billion, US$ 1.8 billion, and US$ 2.4 billion per company, respectively.

Graph 1 - Analyzed subsectors per Market Cap (EUR Millions)



3.3. Variables and Data Collection

In regression models, performance variables serve as dependent variables and are evaluated using a variety of indices (Gozali et al., 2020). While some studies opt for absolute performance measures like gross profit, revenue, and net income (Bonomi Santos & Artur Ledur Brito, 2012; Fried & Tauer, 2015) , these measures are not suitable for this dataset due to the considerable diversity in company sizes and subsectors. Instead, it is more indicated to use dimensionless numerical metrics and indexes such as return on assets (ROA), return on equity (ROE), and return on invested capital (ROIC) (Mayer-Haug et al., 2013). These metrics provide a more reliable means to evaluate a company's performance and allow for meaningful comparisons across companies of various sizes.

Table 5 - Summary of input and outputs variables

Variable	Source	Type	Literature Review
ROE	Refinitiv	Input	(Alda, 2019; Hargrave, 2022; Mayer-Haug et al., 2013)
ROA	Refinitiv	Input	(Fernando et al., 2023; Kocmanová & Dočekalová, 2012; Mayer-Haug et al., 2013)
Environmental Score	Refinitiv	Output	(Clarkson et al., 2011; Guo & Yang, 2024; Sahut & Pasquini-Descomps, 2015)
Social Score	Refinitiv	Output	(Boubaker et al., 2023; Sahut & Pasquini-Descomps, 2015)
Governance Score	Refinitiv	Output	(Amel-Zadeh et al., 2017; Koroleva et al., 2020b)

Source: Author

Return on Asset (ROA) is understood as a financial ratio that indicates how profitable a company is in relation to its Total Assets (Hargrave, 2022). In other words, it

provides an indicator of how efficiently a company is using its assets to generate net income. Therefore, the definition of ROA is:

$$ROA = \frac{Net\ Income}{Total\ Assets} \quad (3)$$

Similarly, Return of Equity (ROE) is also a financial ratio, but indicates how profitable a company is in relation to its total shareholder's Equity (Fernando et al., 2023). Therefore, it is an indicator of the efficiency of the Equity's use to generate net income. Hence, ROE is defined as:

$$ROE = \frac{Net\ Income}{Total\ Equity} \quad (4)$$

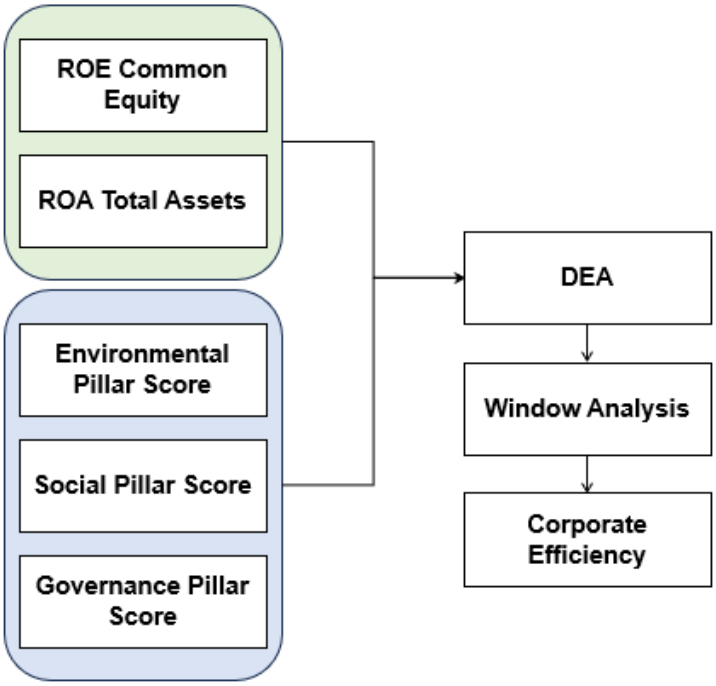
Koroleva et al., (2020), establishes a positive correlation between ESG factors and financial performance, indicating that companies that follow ESG principals have higher performance indexes. Furthermore, through statistical methodology, it was revealed that ESG oriented companies have a 2% higher ROA and 1% higher ROE and ROIC when compared to non-ESG-oriented counterparts.

Similarly, Clarkson et al., (2011) shows that companies with improved over time ESG results, enjoy of a real economic benefit in terms of profitability indexes (such as ROA) and cash flow results, whereas that with declining ESG results, suffer with poorer financial indexes and cash flows. Other articles that contribute to the correlation between ROA, ROE and ESG indexes and performance (Alda, 2019; Cherkasova & Nenuzhenko, 2022; De Lucia et al., 2020; Kocmanová & Dočekalová, 2012; Le et al., 2023; Rahi et al., 2022; Rodríguez-Fernández et al., 2019).

Therefore, given the substantial body of research demonstrating the correlation between ESG indicators and ROA and ROE, these indexes were selected for use in the DEA analysis.

According to the research question, financial factors like ROA and ROE were considered inputs and ESG scores were considered outputs. The research procedure is shown in Figure 4. To streamline and categorize the data, all obtained values were normalized, and DEA models were constructed utilizing RStudio® software.

Figure 4 - Stepwise framework.



4. RESULTS AND DISCUSSIONS

Now, we proceed to show our results. In Section 4.1 we use data collected from the Refinitiv Platform and apply the DEA method to arrive at a rank of the most efficient companies in converting financial resources into ESG achievements. Then, in Section 4.2, we make a more in-depth benchmark analysis with the top-ranked companies.

4.1. DEA

Utilizing the Refinitiv Platform for extracting financial and ESG indicators outlined in section 3.3 for the companies delineated in Table 4, the data presented in Appendix 3 provides all nominal/raw data consolidated by DMU employed in this study, while Appendix 2 exhibits the normalized data derived from the information in Appendix 3. It is important to highlight that the subsequent DEA analysis exclusively utilized the normalized dataset.

Additionally, the normalization process involved converting all ROE, ROA, and E, S, and G scores to a scale ranging from 0 to 1. To achieve this, the lowest and highest values in each category were identified, and the data was normalized within these boundaries, assigning 0 to the lowest value and 1 to the highest. This step was crucial because, as will be discussed in later sections, some ROE and ROA values were negative. Without normalization, these negative values would have compromised the DEA calculations.

Based on the application of the DEA method, which was described in section 3.1, the outcomes of this study are presented in Table 6. The columns in Table 6 represent the average return for each analyzed time window (2018 to 2020, 2019 to 2021, and 2020 to 2022) for every Decision-Making Unit (DMU). The ranking was derived from the slack mean result. Also, it is important to comment that the standard deviation of this study was calculated based on the annual efficiency of each company in the DEA ranking, not on the results of the window analysis averages.

Table 6 - DEA results

Ranking	Company	Subsector	2018-2020	2019-2021	2020-2022	Slacks Mean	Standard Deviation
1	Heidelberger Druckmaschinen AG	Industrial Machinery & Equipment	62,9%	67,9%	65,7%	65,5%	25,4%

2	Nordex SE	Heavy Electrical Equipment	57,8%	63,1%	72,3%	64,4%	10,3%
3	SGL Carbon SE	Electrical Components & Equipment	65,2%	65,2%	59,5%	63,3%	12,3%
4	Norma Group SE	Industrial Machinery & Equipment	58,7%	61,2%	61,2%	60,4%	3,0%
5	Siemens AG	Electrical Components & Equipment	59,8%	60,3%	59,7%	59,9%	0,8%
6	DEUTZ AG	Heavy Machinery & Vehicles	61,2%	58,0%	56,1%	58,4%	7,6%
7	Kion Group AG	Heavy Machinery & Vehicles	54,2%	55,7%	57,7%	55,9%	4,4%
8	GEA Group AG	Industrial Machinery & Equipment	56,5%	55,3%	52,2%	54,7%	4,3%
9	Knorr Bremse AG	Heavy Machinery & Vehicles	49,3%	51,4%	52,8%	51,1%	3,6%
10	Koenig & Bauer AG	Industrial Machinery & Equipment	42,3%	50,2%	51,2%	47,9%	13,0%
11	Duerr AG	Industrial Machinery & Equipment	38,8%	43,9%	48,5%	43,7%	8,2%
12	Pfeiffer Vacuum Technology AG	Industrial Machinery & Equipment	36,6%	45,0%	46,7%	42,8%	11,0%
13	Jungheinrich AG	Heavy Machinery & Vehicles	41,0%	41,3%	40,7%	41,0%	3,1%
14	DMG Mori AG	Industrial Machinery & Equipment	37,6%	39,6%	43,0%	40,1%	6,0%
15	Wacker Neuson SE	Heavy Machinery & Vehicles	29,7%	37,6%	44,7%	37,3%	11,1%
16	WashTec AG	Industrial Machinery & Equipment	25,0%	31,6%	40,8%	32,5%	13,5%
17	Varta AG	Electrical Components & Equipment	14,0%	20,2%	43,6%	25,9%	21,2%

18	Aumann AG	Industrial Machinery & Equipment	24,7%	25,9%	26,6%	25,7%	4,4%

Source: Author

Table 6 is divided into columns showing ranking, company, subsector, average return for every DMU for the periods of 2018-2020, 2019-2021, and 2020-2022, and slack mean followed by the corresponding standard deviation. The slack mean was the deciding factor for the ranking classification, calculated as the average of the average return for each period. The standard deviation is a statistical measure that quantifies the amount of variation or dispersion in the collected data, often used to describe the spread of data points in a dataset.

The three top companies we found were Heidelberger Druckmaschinen AG, Nordex SE, and SGL Carbon SE respectively. We will make a more in-depth benchmark analysis of each of them in the following sections.

Heidelberger presented the highest slack mean, i.e., the highest average of the average return per DMU, and even though the company presented negative results during the pandemic, it is one of the leading and most established conglomerates in the printing industry subsector. Nordex SE is specialized in wind turbines operating all over the world, their business strategy focuses on producing environmentally and climate-friendly power, with operations in all significant wind markets, excluding China. SGL Carbon is an international leader in carbon-based technologies, serving key markets such as Mobility, Energy, Digital, Industrial Applications, and Chemistry. Furthermore, we also consider Siemens AG, the largest company in the M&E sector, and even though it was not the top-ranked company it has shown impressive results, such as the lowest standard deviation in our ranking. Notably, the Electrical Equipment & Components subsector is present in two out of the five top companies and concentrates the largest market capitalization of the sector. Another interesting fact is that the Heavy Machinery & Vehicles subsector presents a low standard deviation across the ranking, with an average of 5.96%.

4.2. Analysis of the benchmarks

In this section, in order to get a more in-depth understanding of the top-ranked companies in our study, we make a qualitative analysis of these companies describing each company's processes within their specific context, sources of revenue streams,

diversity of markets and geography penetration and their strategic effectiveness through the Porter's Five Forces framework. Resource-Based View (RBV) theory is also used to identify how the companies are deploying their resources, and if Sustained Competitive Advantages are achieved (with a focus on ESG performances).

4.2.1. Heidelberger Druckmaschinen AG

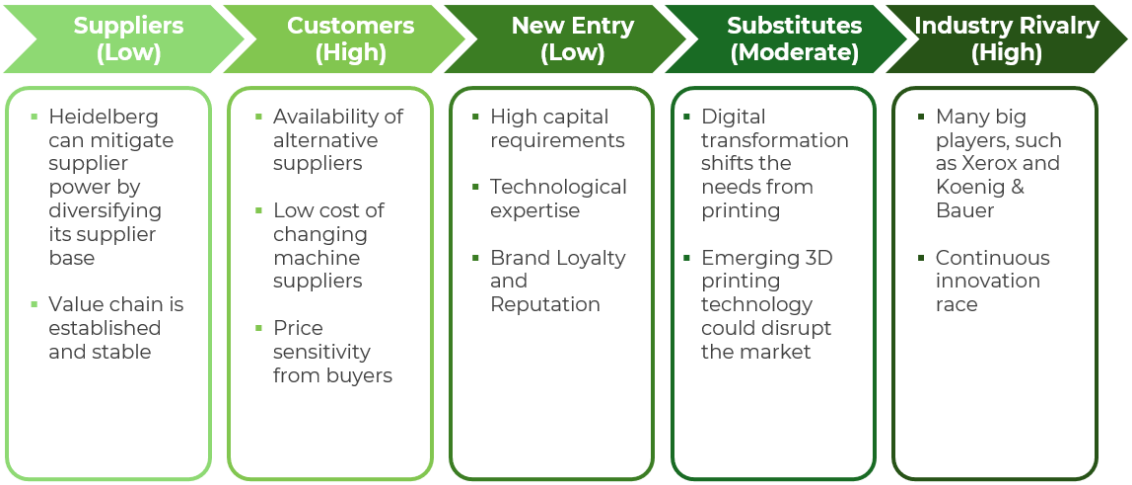
Heidelberger Druckmaschinen AG (Heilderberg) is a leading technology company in the printing industry, renowned for quality and innovation. The almost 175-year-old company operates in the global printing industry, with around 87% of sales generated internationally, across Europe, the Americas, Asia-Pacific, and Africa (Heidelberger Druckmaschinen AG, 2024.).

The company operates through three primary segments: Printing solutions, encompassing sales from offset printing, label printing, narrow web printing, and digital printing (Heildelberg IR, 2024); Packaging Solutions, which focuses on packaging and related machinery; and Technology Solutions, which comprises Zaikio (independent cloud-based collaboration platform for the printing industry), E-Mobility, and other software (Hartung, 2020). For its revenue composition, the company has four streams of income:

- Direct sale of Machinery and Equipment: Primary revenue from the sale of Printing presses, Package printing, Label printing, and commercial printing.
- Consumables and Spare Parts: Sold with machinery to support ongoing operations and maintenance.
- Charging Stations: Sold within the e-mobility sector, representing a newer revenue stream.
- Services and Software Solutions: Includes installation services, maintenance, long-term service contracts (O&M) and Cloud software for companies' clients. (Heidelberger Druckmaschinen AG, n.d.)

Using the five forces of Porter analysis to better comprehend the dynamic of Heidelberger Druckmaschinen AG, we have Figure 5.

Figure 5 - Heidelberger Druckmaschinen AG Five Forces of Porter



Source: Author

Heidelberger Druckmaschinen AG operates in a highly competitive environment. The company's ability to innovate, maintain strong customer relationships, and manage supplier partnerships are critical to its success. While barriers to entry protect the company to some extent, there is a constant threat of technological substitution and price sensitivity from buyers.

Heidelberger Druckmaschinen AG has made significant actions to integrate Environmental, Social, and Governance (ESG) principles into its operations. The company is committed to being sustainable in all metrics and has a clear long-term vison and strategic goals. Some milestones achieved are resumed in Table 7.

Table 7 - ESG milestones achieved by Heidelberger Druckmaschinen AG

ESG Dimension	**Milestones**
Environmental Actions	Integration of Lifecycle assessment in their ISO 14001 management system. CO2 neutralization of all folding machines as standard. Photovoltaic system with 3.6 MWp at production side in Amstetten Combined quality and environmental management system (ISO 9001 and ISO 14001) at all European production sites.
Environmental long-term goals	HEIDELBERG aims to achieve climate neutrality at its locations in two stages: purchasing emission certificates until 2030 and complete climate neutrality by 2040
Social Actions	Mentoring program to promote young female employees - HEIDELBERG is committed to promoting diversity and inclusion within its workforce. HEIDELBERG provided more than 11,000 free meals in the fiscal year 2021/2022 for people in necessity. Supports projects at 12 schools that give children hands-on experience of technology and science.
Governance actions	The company has established an ESG Council that includes the highest management levels to steer the company's sustainability strategy. HEIDELBERG is aligned with the principles of the UN Global Compact, emphasizing human rights, labor standards, environmental protection, and anti-corruption.

Source: Heidelberger Druckmaschinen AG (2024); Heidelgerber IR (2024)

Despite Heidelberg's leadership in ESG initiatives, financial analysis reveals fluctuating performance, notably with negative Return on Equity (ROE) and Return on Assets (ROA) during the COVID-19 impacted years of 2020 and 2021 (Table 8). This led to an eventual debt restructuring in 2021 to guarantee that the company remained solvent.

Nevertheless, Heidelberger commitment to advancing its ESG goals remained steady, with notable improvements in its Governance score, and stable results in the E and S scores. As Koroleva et al., (2020) and the RBV theory pointed out, ESG factor are rare and difficult-to-imitate resources. Therefore, because of Heidelberger's efficient value-creation strategy, the company achieved a Sustained Competitive Advantage in ESG performance, despite poor financial results.

Table 8 - Consolidated financial and ESG data for Heidelberger Druckmaschinen AG

Fiscal Year	**FY2022**	**FY2021**	**FY2020**	**FY2019**	**FY2018**
ROE	18,8	-27,5	-114,0	5,6	4,0
ROA	1,5	-1,8	-13,9	0,9	0,6
E score	57,5	55,6	57,6	54,7	55,8
S score	46,2	46,9	53,1	53,0	48,2
G score	60,2	64,6	60,7	50,6	54,3

Source: Refinitiv, 2023

Therefore, Heidelberger Druckmaschinen AG holds a distinctive position as an outlier among the Machinery and Equipment (M&E) companies analyzed in this study – due to its unique combination of negative financial inputs (ROE and ROA), sustained competitive advantages and stable ESG outputs. Following the normalization process, as shown in Table 9, these negative inputs were scaled to a range between 0 and 1.

Table 9 - Normalized consolidated data for Heidelberger Druckmaschinen AG

Company	**year**	**DMU**	**ROA**	**ROE**	**E**	**S**	**G**
HDDG.DE	2018	HDDG.DE_2018	0,544	0,787	0,632	0,473	0,568
HDDG.DE	2019	HDDG.DE_2019	0,554	0,798	0,620	0,530	0,528
HDDG.DE	2020	HDDG.DE_2020	0,066	0,000	0,653	0,531	0,639
HDDG.DE	2021	HDDG.DE_2021	0,465	0,577	0,630	0,458	0,682
HDDG.DE	2022	HDDG.DE_2022	0,574	0,886	0,651	0,449	0,633

Source: Refinitiv, 2023

This normalization enabled the inclusion of Heidelberger in the DEA calculation, ensuring a comprehensive analysis. However, it also produced a result with a standard deviation of 25,4%, considerably above the other top five companies from the ranking. Such a high standard deviation indicates a large spread in the data points around the mean. This spread suggests that the values in the dataset vary widely from the average value,

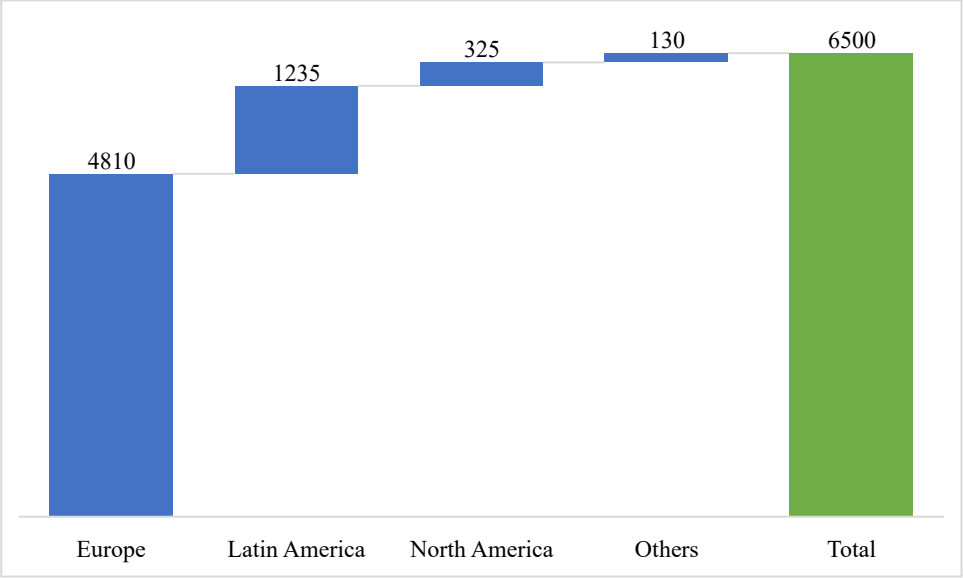
which in turn implies high variability and less consistency. This way, Heidelberger was chosen to be excluded from the ranking, since its results are not stable enough to elect the company and an example and benchmark to be followed in the German M&E sector.

4.2.2. Nordex SE

Nordex SE is a global specialist in onshore wind turbines. Founded in 1985, the company has installed turbines with a combined output of 50 gigawatts (GW) in over forty countries (11,400 wind turbines worldwide). Nordex operates as an integrated full-service provider, which means that they not only deliver wind turbines, but also construct complete wind farms, and offer full operation and maintenance (O&M) service for its customers. They focus primarily on the onshore market to avoid the high investment and risks associated with offshore technology (Nordex SE Investors Relations, 2024a).

Their business model emphasizes environmental and climate-friendly power generation, operating in all major wind markets except China, where it primarily sources components, due to the dominance of local suppliers. Therefore, as Graph 2 shows, their revenue is mostly concentrated in European markets (74%) but has considerable exposure to the Latin America market (19%).

Graph 2 - Nordex SE's Revenue in EUR Millions in 2023



Source: Nordex SE Investors Relations (2024)

Nordex SE's primary product line is the Delta4000 series, which includes wind turbines in the 4 MW, 5 MW, and 6 MW+ classes. These turbines are designed for high, medium, and low-wind onshore locations and are known for their modular design,

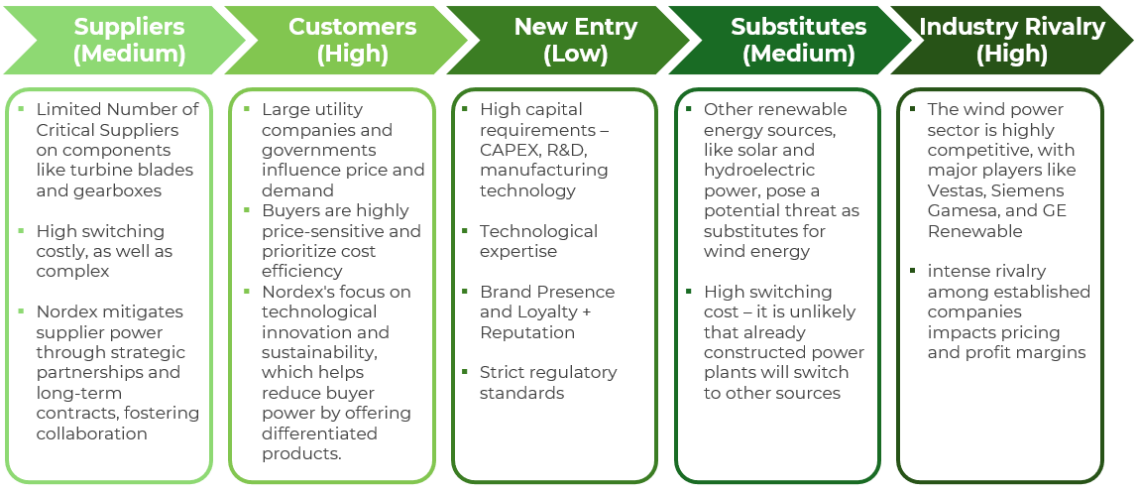
allowing for customization based on specific market and location requirements. Nordex also provides rotor blades, nacelles, hubs, and towers, with some components produced in-house and others by specialized manufacturers (Nordex SE, 2024b).

The company's revenue streams are primarily divided into two segments:

- Projects Segment: This includes all activities related to the development, production, assembly, and commissioning of wind turbines. It also encompasses project development, particularly in markets outside Europe, and represented 90% of the company's revenue in 2023.
- Service Segment and O&M: This involves the provision of services and products for existing turbines post-handover, such as maintenance, remote monitoring, repairs, and technical upgrades. The service contracts, which can extend up to 35 years, offer various levels of service from basic maintenance to comprehensive modernization. (Nordex SE Investors Relations, 2024a).

Using the five forces of Porter analysis to better comprehend the dynamic of Nordex SE, we have Figure 6.

Figure 6- Nordex SE Five Forces of Porter



Nordex SE operates in a highly competitive market characterized by high entry barriers and significant buyer power. The company's strategic focus on innovation, sustainable solutions, and strong long-term partnerships enables it to navigate these competitive forces. However, as we will see in table 11, the intense rivalry among companies is a major concern to the company as its financial results have deteriorated in the analyzed period, indicating a decline in profitability.

As of future innovations, the company created a Joint Venture to invest in the Green Hydrogen production market, with the announcement of an Alkaline Electrolyzer prototype, to be tested and assembled in Spain (Energy News, 2024). Moreover, Nordex has signed a memorandum of understanding (MoU) with Brazil's Rio Grande do Norte state government to develop an industrial chain of hydrogen production, using low-carbon energy (solar and wind), increasing its exposure to markets outside Europe (Lucas Morais, 2023; Wagner Freire, 2023).

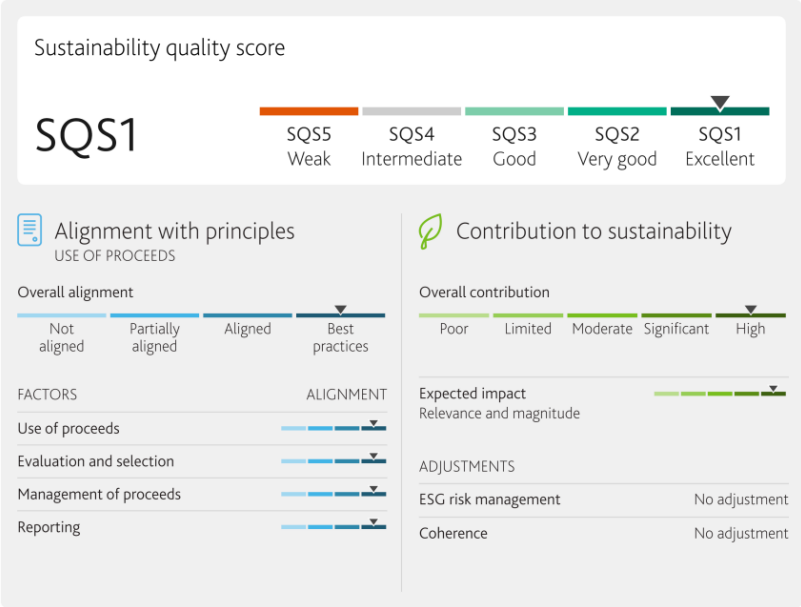
Table 10 - Nordex SE main ESG achievements and long-term goals

ESG Dimension	**Milestones**
Environmental	Provide fully recyclable blades by 2032. Achieve climate neutrality by 2023 (Scope 1+2) and continuously improve climate impact. Achieve zero production waste to landfill by 2025
Social	Reduce accidents to a lost time injury frequency of <1.5. Achieve a minimum of 25% female representation in management positions. Reduce the voluntary turnover rate to below 5 percentage points of the market average by 2025. Developed a comprehensive mental health strategy for employees
Governance	Promote responsible and ethical business conduct internally and engage in a positive impact in the supply chain. 166 conducted audits of Nordex-specific component suppliers as well as construction and service-related suppliers Forty-six percent of employees completed a course on preventing corruption

Source: Nordex SE (2024a); Nordex SE Investors Relations (2024)

Nordex SE is committed to environmental, social, and governance (ESG) principles, as summarized in Table 10. Furthermore, the company has used their environmental performance and ranking to issue Green Convertible Bonds, which offer lower Yield compared to normal Bonds. Moody's has assigned Nordex with an SQS1 Sustainability Quality Score (excellent), as shown in Figure 7, which made the company eligible for the Green Bond emission (Moody's Investors Service, 2023).

Figure 7 - Moody's quality score for Nordex Green Bond Emission



Source: Moody's Investors Service (2023)

Regarding its DEA results, Nordex is in a unique situation. As shown in Table 11, the ROA and ROE inputs were negative for all years of the analysis, deteriorating further in 2022. This suggests that the company is becoming increasingly less efficient at generating profit from its assets and equity – declining profitability – which links with the Five Forces of Porter analysis, suggesting that the management has not been able to navigate the intense rivalry among competitors and the significant power of buyers properly to generate revenue.

Table 11 - Consolidated financial and ESG data for Nordex SE

Fiscal Year	**FY2022**	**FY2021**	**FY2020**	**FY2019**	**FY2018**
ROE	-51,3	-25,1	-17,1	-10,1	-10,4
ROA	-11,2	-5,4	-3,1	-2,1	-2,9
E Score	62,9	64,3	61,8	56,3	56,8
S Score	88,9	87,2	82,0	50,2	51,1
G Score	87,2	84,6	76,4	49,3	40,0

Source: Refinitiv, 2023

As shown in 4.1.1 for Heidelberger, the existence of negative inputs does not impair the DEAs calculation feasibility, since the DMUs inputs and outputs are normalized (using a 0 to 1 range).

Despite its financial challenges, Nordex has maintained an exemplary focus on environmental sustainability and social responsibility efforts, evidenced by a consistent

upward trend in the E and S scores (Table 11). Additionally, the company has shown substantial improvement in its G score, more than doubling since 2018, indicating better governance practices.

Table 12 - Normalized consolidated data for Nordex SE

Company	year	DMU	ROA	ROE	E	S	G
NDXG.DE	2018	NDXG.DE_2018	0,43	0,69	0,64	0,51	0,41
NDXG.DE	2019	NDXG.DE_2019	0,46	0,69	0,64	0,50	0,51
NDXG.DE	2020	NDXG.DE_2020	0,42	0,65	0,70	0,87	0,81
NDXG.DE	2021	NDXG.DE_2021	0,35	0,59	0,73	0,93	0,90
NDXG.DE	2022	NDXG.DE_2022	0,15	0,42	0,71	0,96	0,93

Source: Refinitiv, 2023

Considering that, unlike Heidelberger, which had a 25% standard deviation in its results, Nordex SE has a 10% standard deviation, even with its negative inputs, the company cannot be classified as an outlier in the DEA analysis. Nordex is, in fact, an example in the M&E sector, suggesting that (I) it is possible to maintain a strong and resilient ESG performance despite poor financial results, and (II) the necessity to achieve profitability should not imply in the abandonment of long-term sustainable goals.

As Barney (1991) proposed in his RBV works, value-creating strategies and be derived from assets and resources, mainly: (i) Physical capital assets, (ii) Human capital resources or (iii) Organizational capital resources. Companies aiming for better ESG outcomes should examine how Nordex utilizes these assets and resources and take inspiration from their actions to implement more effective value-creation strategies in their management and future agendas.

4.2.3. SGL Carbon SE

SGL Carbon, established in 1992, is a global leader in carbon-based solutions, specializing in specialty graphite, carbon fibers, and composites. The company serves key industries including climate-friendly mobility, semiconductor technology, LED, solar and wind energy, and lithium-ion battery manufacturing (SGL Carbon, 2024d, 2024a). Additionally, SGL Carbon provides innovative solutions for the chemical sector and various industrial applications and distinguishes itself by offering comprehensive products along the entire value chain, from raw materials to finished components. Furthermore, the company has a global presence, as shown by its Sales Revenue by region in Table 13.

Table 13 - SGL Carbon SE Sales Revenue by Target Region (EUR millions)

Region	**2023**	**% of total**	**2022**	**% of total**
Germany	282,9	26,0%	294,5	25,9%
Europe ex-Germany	207,5	19,1%	236,2	20,8%
USA	243,5	22,4%	213,8	18,8%
China	178,3	16,4%	181,1	15,9%
Asia ex-China	123,7	11,4%	148,1	13,0%
Others	53,2	4,9%	62,2	5,5%
Total	1089,1	100%	1135,9	100%

Source: SGL Carbon Investor Relations (2024a)

SGL's operations are structured into four business units: Graphite Solutions (GS), Process Technology (PT), Carbon Fibers (CF), and Composite Solutions (CS) (Our Business Units at glance). The company categorizes its market segments and clients into five distinct groups: Mobility, Energy, Digital, Industrial Applications, and Chemistry (Markets & Solutions).

Table 14 - Overview of SGL Carbon Business Units

Business Units	**Description**	**Central Functions & Services**
Graphite Solutions (GS)	GS focuses on high-value products such as specialty graphite components with coatings, critical in semiconductor production, electromobility, and renewable energy. The unit is a notable European supplier of graphite anode materials for lithium-ion batteries.	-Synthetic fine grain graphite blocks, expanded natural graphite. - Graphite specialties - Graphite anode material - Materials for fuel cells
Process Technology (PT)	PT specializes in constructing and repairing large industrial systems, particularly for the chemical industry. It designs and manufactures graphite heat exchangers, columns, and pumps for corrosive media. Also Includes O&M services.	- Process solutions - Equipment for corrosive applications -Components & assemblies - Spare parts & services
Carbon Fibers (CF)	CF produces textile and carbon fibers essential for composite applications. Known for high tensile strength and low weight, these fibers are used in the automotive and wind industries, particularly in offshore wind turbines.	- Precursor & acrylic fibers - Carbon fibers - Non-crimp & woven fabrics -Pre-impregnated materials
Composite Solutions (CS)	This unit focuses on custom composite solutions using carbon and fiberglass, especially for the automotive industry. CS produces components for high-tech applications requiring strength and low weight, with a focus on battery housings and GRP leaf springs.	- Composite parts (large & small series) - Wet friction - Insulation materials

Sources: SGL Carbon (2024c); SGL Carbon Investor Relations (2024a)

Table 14 provides an overview of the four business units, while Table 15 details the market segments, breaking them down into specific subsectors.

Table 15 - Subsectors from the market segments

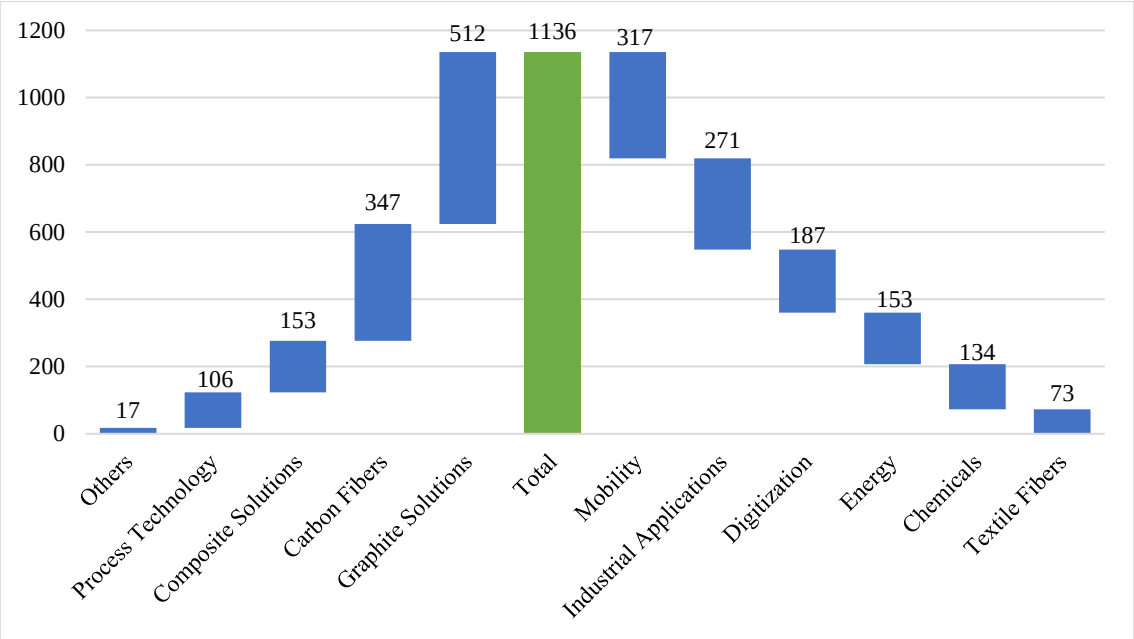
Market Segment	Subsector	
Mobility	- Automotive	- Aerospace

	- Aerospace	
Energy	- Energy conservation - Energy Storage	- Photovoltaic - Wind Energy
Digital	- Compound Semiconductor and LED	- Semiconductor
Industrial Applications	- Sealing Technology - High Temperature Applications	- Refractory Industry
Chemistry	- Chemistry - Pharmaceutics	- Process Technology

Source: SGL Carbon (2024b); SGL Carbon Investor Relations (2024a)

Additionally, Graph 3 illustrates the company's revenue distribution across the business units and market segment.

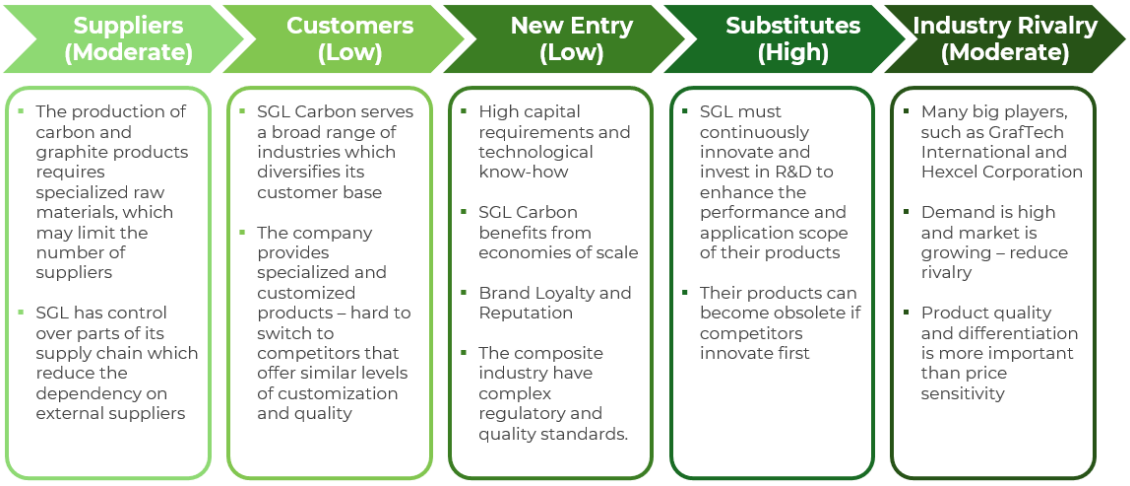
Graph 3 - SGL Carbon 2022 Group Sales Revenue for Business Units and Market Segments (EUR Million)



Source: Adapted by the author from SGL Carbon Investor Relations (2024a)

Figure 8 presents SGL's analysis using Porter's Five Forces to illustrate the company's market position. SGL Carbon SE operates in a competitive yet highly specialized industry with substantial barriers to entry. The company benefits from a diverse customer base, a strong focus on innovation, and strategic investments in high-growth markets like semiconductors. As a result, both supplier and customer bargaining power are low, and competitive rivalry is moderate. However, the threat of substitutes remains high, necessitating continuous investment in R&D to avoid obsolescence.

Figure 8 - SGL Carbon Five Forces of Porter



Source: Author

As an energy-intensive company, SGL places sustainable management and action at the core of its corporate strategy. Recognizing the importance of ecological, social, and governance responsibilities in today's world, SGL has earned multiple ratings and certifications, including an AA rating on MSCI ESG, ISO 14001, and ISO 50001. Table 16 summarizes the company's long-term ESG goals and milestones achieved.

Table 16 - SGL Carbon main ESG achievements and long-term goals

ESG dimension	**Milestones**
Environmental	Fifty percent CO2 emissions reduction by 2025 Climate neutral by 2038 One percent energy intensity reduction per year Implementation of Circular Economy culture and strategies Implementation of biomass systems to reduce CO2 emissions
Social	Five percent reduction of Lost Time Injury (LTI) frequency rate per year - 2022 Maintain a 20% women's quota (senior management) Twenty percent Improvement of SGL Performance Culture Index 100% Training of all production employees on the code of conduct and human rights until 2024
Governance	100% signature of supplier code of conduct Review of suppliers' ESG performance Zero tolerance of compliance violations Re-certification of ISO 37301 certification Investigation and sanctioning of compliance violations, with no confirmed cases of fraud, bribery, or corruption.

Source: SGL Carbon Investor Relations (2024b, 2024a)

Concerning its DEA results, SGL faces similar challenges to Nordex and Heidelberger, with negative inputs in the ROA and ROE indexes, as shown in Table 17. However, unlike Nordex and Heidelberger, SGL's problems began before the COVID-19 crisis. Today, the company is more profitable than it was in 2018, indicating improved efficiency in generating profit from its assets and equity.

Table 17 - Consolidated financial and ESG data for SGL Carbon

Fiscal Year	FY2022	FY2021	FY2020	FY2019	FY2018
ROE	26,7	25,5	-41,6	-18,9	10,2
ROA	8,8	5,8	-9,4	-5,8	3,2
E Score	70,4	71,1	74,0	69,8	70,3
S Score	59,3	62,4	62,0	66,2	67,4
G Score	89,0	85,1	79,8	72,7	67,5

Source: Refinitiv, 2023

In contrast to Nordex, which achieved exemplary ESG scores despite negative financial indicators in all years, SGL maintained its E scores but saw a continuous decline in its S scores (Table 17). The reason for SGL's third-place position in the DEA analysis is its improving G scores, which increased even during the crisis cycle.

Table 18 - Normalized consolidated data for SGL Carbon

Company	year	DMU	ROA	ROE	E	S	G
SGCG.DE	2018	SGCG.DE_2018	0,63	0,83	0,80	0,70	0,71
SGCG.DE	2019	SGCG.DE_2019	0,33	0,63	0,79	0,69	0,77
SGCG.DE	2020	SGCG.DE_2020	0,21	0,48	0,84	0,64	0,85
SGCG.DE	2021	SGCG.DE_2021	0,71	0,93	0,81	0,64	0,91
SGCG.DE	2022	SGCG.DE_2022	0,81	0,94	0,80	0,60	0,95

Source: Refinitiv, 2023

This does not diminish SGL's status as a benchmark for ESG actions in the M&E sector in Germany. However, it indicates that the company did not achieve the remarkable milestones from 2018 to 2022 that Heidelberger and Nordex did. It is important to highlight that in other aspects, SGL outperforms these benchmarks, particularly in (i) profit stability, (ii) diversity of products and markets served, and (iii) global impact. This way, it is possible to state that, according to the RBV theory, SGL has a Sustained Competitive Advantage over Nordex and Heidelbeger in terms of business management. Moreover, on ESG value-creation and resource employment, SGL has an advantage against the other worse achievers from the DEA ranking.

4.2.4 Siemens AG

According to our DEA calculations, Siemens AG ranks as the fifth best company in terms of transforming its financial results into ESG achievements, trailing behind Heidelberger AG, Nordex SE, SGL Carbon SE, and Norma Group SE. However, as discussed previously in section 4.2, Siemens is the largest company in the M&E sector, with a market capitalization larger than all the other companies combined. Additionally, the standard deviation of Siemens' DEA results is only 0.8%, indicating a high degree of

consistency and making it imperative to test it as a benchmark given the solidity of these results.

Siemens AG was founded by Werner von Siemens and Johann Georg Halske on October 1, 1847. Initially, a small telegraph manufacturing company in Berlin, Germany, Siemens has since evolved into one of the world's largest industrial manufacturing companies. Today, the technology company operates in nearly every country and employs approximately 320,000 people (as of September 2023) (Siemens investor relations, 2024). Table 19 provides a summary of Siemens' business lines and segments.

Table 19 - Siemens business lines, key products, and markets

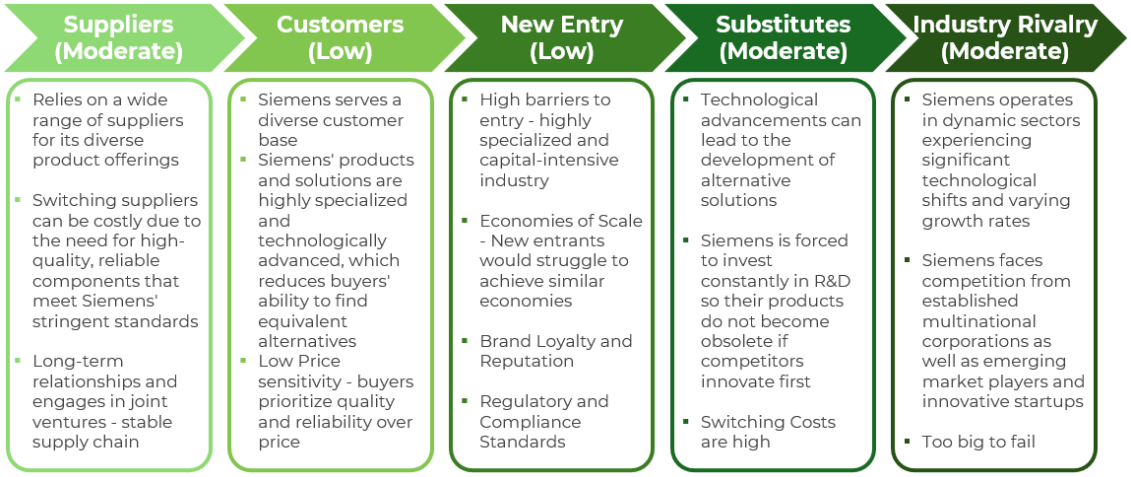
Business Lines	**Overview**	**Key Products**	**Market Segments/Industries**
Digital Industries	Portfolio of products and systems for automation used in discrete and process industries. This includes factory automation systems, numerical control systems, servo motors, drives, inverters, and integrated automation systems for machine tools and production machines.	Automation Systems Software Solutions Mendix Platform Digital Marketplaces Lifecycle Services	Automotive Machine-building Pharmaceutical and Chemicals Food and Beverage Electronics and Semiconductor
Smart Infrastructure	Provides products, systems, solutions, and services to support the transition from fossil to renewable energy sources and the development of smarter buildings	Building Technologies Electrification Solutions Electrical Products	Infrastructure Developers Process Industries (Oil & Gas) Manufacturing Utilities
Mobility	Mobility delivers solutions for rail and road transportation, emphasizing automation and digitalization to enhance the efficiency and sustainability	Rail Systems Automated and Digital Rail Solutions Road Traffic Solutions	Public and Private Railway Operators Urban and Interurban Transport Systems Logistics Companies
Siemens Healthineers	Healthineers focuses on medical technology and diagnostics, offering solutions to healthcare providers worldwide	Imaging Systems Diagnostic Solutions Digital Health Services	Hospitals and Clinics Diagnostic Laboratories Healthcare Professionals
Siemens Financial Services	Provides financial solutions to support Siemens’ sales and customer investments, focusing on areas such as energy, healthcare, and industrial automation.	Project and Structured Finance Equipment and Technology Finance	Energy Sector Healthcare Sector Industrial Sector

Source: Siemens investor relations (2024)

The extensive range of market segments and business lines explains the substantial size of Siemens AG. Furthermore, when developing the Five Forces of Porter

analysis for the company, this size was a critical factor in all five dimensions of the analysis. Figure 9 presents the Five Forces of Porter analysis, to better comprehend the company's business situation.

Figure 9 - Siemens Five Forces of Porter analysis.

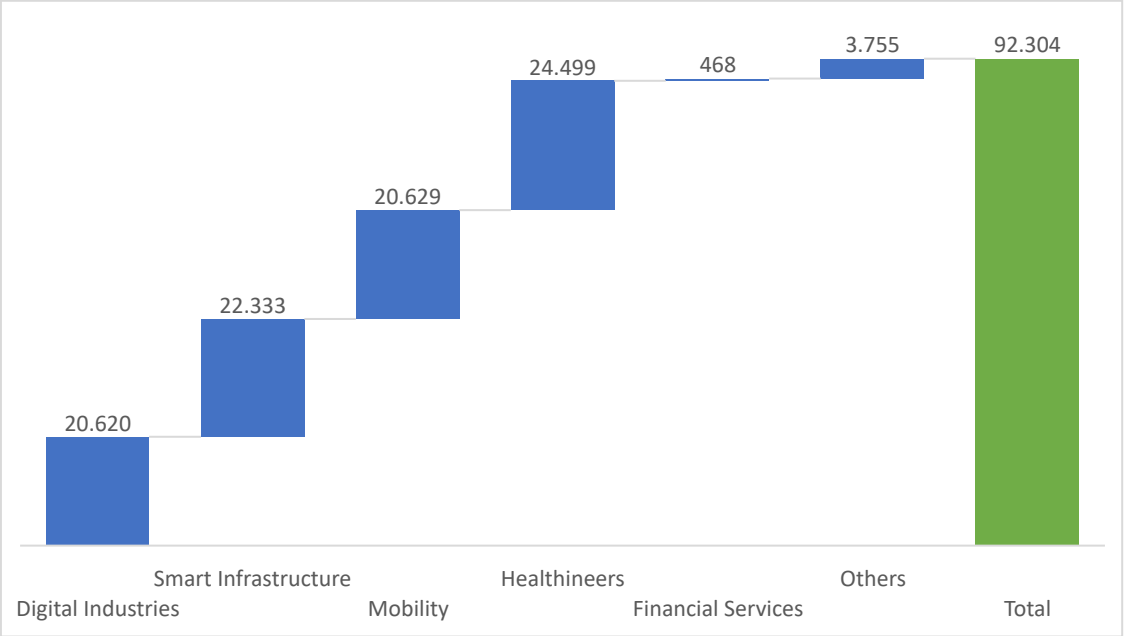


Source: Author

Siemens operates in a competitive environment shaped by high barriers to entry, capital intensive and specialized industry, with a constant threat from substitutes due to technological advancements. The company’s size and continuous investment in R&D provides technological advantages and economies of scale that improve all five Porter dimensions for the company. Additionally, Siemens' ability to leverage digitalization and smart technologies positions it favorably to maintain its competitive edge.

Complementary of the Five Forces of Porter analysis, Graph 4 and 5, show Siemens’ revenue by business segment and geography.

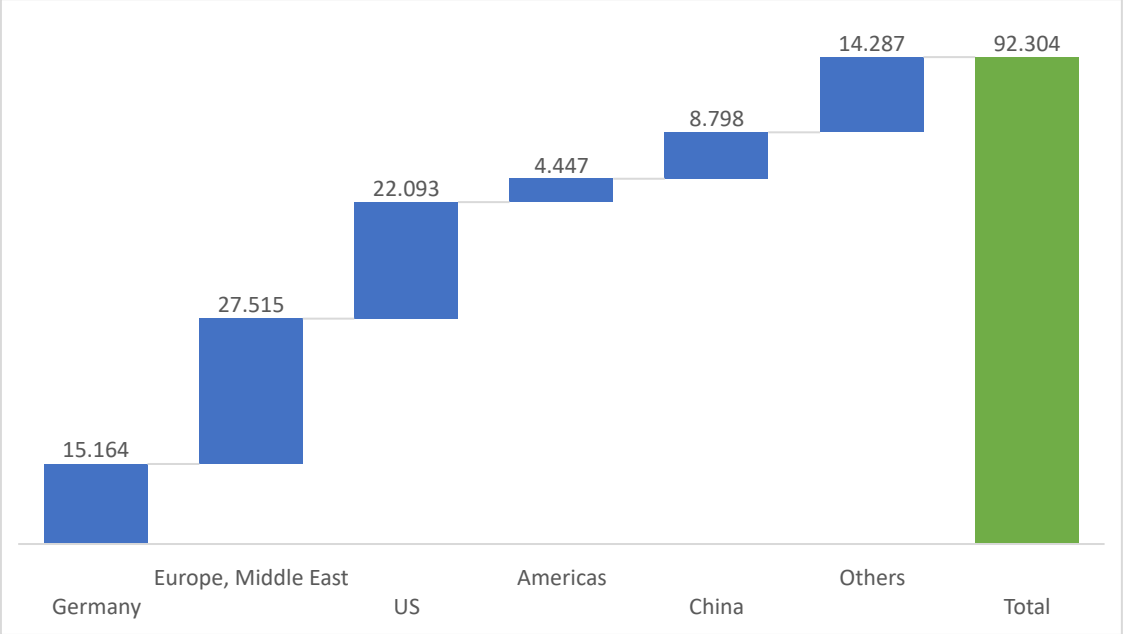
Graph 4 - Siemens revenue by Business Line (ERU millions)



Source: Siemens investor relations (2024), made by author

The combination between size, diversification of products and markets, establishment of Joint Ventures, and long-term suppliers' relationships guarantee the company stability, sustained competitive advantage and position as the leader company in the M&E sector in Germany.

Graph 5 - Siemens revenue by Region (EUR millions)



Source: Siemens investor relations (2024), made by author

In regard to Siemens ESG achievements, Siemens uses a DEGREE framework, which outlines the company's comprehensive approach to sustainability (Siemens investor relations, 2024b). The framework focuses on six key areas: Decarbonization, Ethics, Governance, Resource Efficiency, Equity, and Employability. DEGREE guides Siemens' efforts across its operations, including setting clear priorities and measurable ambitions in key ESG area. Table 20 summarizes the company's goal and milestones achieved.

Table 20 - Siemens ESG goals and achievements

DEGREE	**Goals**	**Milestones**
Decarbonization	Aims to achieve net zero operations by 2030. Net Zero Supply Chain -net zero emissions in the supply chain by 2050	Siemens reduced Scope 1 and Scope 2 emissions by 32,000 metric tons of CO2e or 8% compared to fiscal 2022
Ethics	Siemens is committed to training 100% of its employees on its Business Conduct Guidelines every three years	The program has been rolled out to 71% of all employees worldwide
Governance	ESG-Secured Supply Chain: Siemens requires supplier commitment to the Supplier Code of Conduct and integrates ESG criteria into long-term incentives	Supplier commitment to the Supplier Code of Conduct Implementation of incentives based on ESG criteria
Resource Efficiency	Implement Robust Eco Design for 100% of product. Increase the purchase of secondary materials for metals and resins and achieve significant waste-to-landfill reductions	Reduced landfill waste by 15% compared to the base year 2021. Compliant with ISO 50001
Equity	Thirty percent female representation in top management by 2025 Increase Employee's share participation plan	Female representation at 31.1% today Forty-three percent of all employees worldwide participating in the share plan
Employability	Employee Assistance Program: The goal is to expand access to 100% by 2025, ensuring a strong focus on employee health and safety	Zero fatalities in 2023, High-consequence work-related injuries and Lost time injuries (LTI) down 28% and 5% from 2023, respectively

Source: Siemens investor relations (2024b)

Tables 21 and 22 presents Siemens' ESG and Financial indicators for the DEA analysis. Different from Heidelberger, Nordex and SGL, who experienced negative inputs (ROA and ROE) for at least one year of the analysis periods, Siemens financial indicators remained positive during all the years, even during the COVID-19 crisis. Which further restates the company stability and competitive advantage as shown in the Five forces of porter analysis.

Table 21 - Consolidated financial and ESG data for Siemens

Fiscal Year	**FY2022**	**FY2021**	**FY2020**	**FY2019**	**FY2018**
ROE	8,0	12,7	9,4	10,0	11,8
ROA	3,0	4,3	3,0	3,6	4,0

E Score	88,2	88,1	87,5	85,4	84,6
S Score	81,8	81,7	81,7	79,6	80,0
G Score	87,2	90,7	92,9	91,7	86,3

Source: Refinitiv

Moreover, Siemens' diversification across products, markets, and geographies further mitigates its intrinsic risks. In terms of ESG achievements, all three indexes grew from 2018 to 2022, consistently exceeding eighty points (except for S in 2019), demonstrating the efficiency of the company's sustainability framework and initiatives.

Table 22 - Normalized consolidated data for Siemens

Company	**Year**	**DMU**	**ROA**	**ROE**	**E**	**S**	**G**
SIEGn.DE	2018	SIEGn.DE_2018	0,66	0,84	0,96	0,85	0,92
SIEGn.DE	2019	SIEGn.DE_2019	0,64	0,83	0,97	0,84	0,98
SIEGn.DE	2020	SIEGn.DE_2020	0,62	0,82	0,99	0,87	0,99
SIEGn.DE	2021	SIEGn.DE_2021	0,67	0,84	1,00	0,87	0,97
SIEGn.DE	2022	SIEGn.DE_2022	0,62	0,81	1,00	0,87	0,93

Source: Author

Thus, Siemens serves as a benchmark. While some may argue that Siemens' size makes it an outlier compared to other companies in the M&E sector, its fifth best DEA result, lowest standard deviation, and strong metrics across all areas counter this argument. Other companies can draw valuable lessons and inspiration from Siemens' business and sustainability practices, independently of size differences.

Moreover, as Clarkson et al., (2011) demonstrated, not all firms possess the capacity to emulate the strategy of others; only those with the right management and financial capabilities do. Therefore, it is also possible to infer that Siemens' ESG indicators are rare and difficult-to-imitate resources that lead to a Sustained Competitive Advantage, which better improves the company cash flow generation and overall performance.

4.2.5 Concluding Remarks

In our study, we have ranked the most effective companies in transforming financial resources into ESG accomplishments within the M&E sector in Germany, utilizing the DEA Framework., resulting in the top-ranked firms: Heidelberger Druckmaschinen AG, Nordex SE, SGL Carbon SE and Siemens AG.

We then performed a benchmark analysis using Porter's Five Forces framework, Resource-Based View (RBV) Theory and qualitative analysis to better understand the

competitive dynamics of each company. Benchmarking, which compares business processes and performance metrics to industry bests and best practices from other companies (Anand & Kodali, 2008), is crucial for organizations aiming to enhance performance by identifying gaps, setting goals, and implementing strategies derived from industry leaders. We considered two types of benchmarking: Competitive Benchmarking and Functional Benchmarking.

Competitive Benchmarking compares an organization's performance directly against its competitors, providing insights into relative positioning and areas for improvement that can lead to a competitive advantage (Camp, 1989). This method is useful for understanding market standards and identifying strengths and weaknesses relative to direct competitors.

Functional Benchmarking compares similar functions or processes across different organizations within the same industry (Camp, 1989), allowing companies to gain insights into best practices and innovative solutions prevalent in other companies performing similar functions.

For Competitive Benchmarking, we focused on Nordex SE and SGL Carbon SE, as Heidelberger Druckmaschinen AG was considered an outlier. For Functional Benchmarking, we considered Siemens AG.

Heidelberger Druckmaschinen AG is a leading technology company in the printing industry and operates in a highly competitive environment. Furthermore, the company ranked first in the DEA calculations with a slack mean return overinvestment per DMU of 65.5%. However, its financial analysis revealed fluctuating performance, particularly with negative ROE and ROA during the COVID-19-impacted years of 2020 and 2021, reflected in its high standard deviation of results. Consequently, it was considered an outlier and was not elected a benchmark for this analysis.

Nordex SE is a global specialist in onshore wind turbines and operates as an integrated full-service provider. Their business model emphasizes environmental and climate-friendly power generation, presenting a slack mean DEA result of 64.4% combined with a standard deviation of 10.3%. Despite financial challenges, Nordex has maintained strong ESG performance, evidenced by a consistent upward trend in E and S scores and substantial improvement in its G score. This highlights the possibility of maintaining strong ESG performance despite poor financial results and underscores the

necessity of achieving profitability without abandoning long-term sustainable goals. Therefore, Nordex is a clear benchmark for the M&E sector.

SGL Carbon SE is an international leader in carbon-based solutions, SGL specializes in specialty graphite, carbon fibers, and composites, serving key industries including climate-friendly mobility and renewable energy. SGL operates in a competitive yet highly specialized industry with substantial barriers to entry but faces a high threat of substitutes, necessitating continuous R&D investment. SGL's DEA results show similar challenges to Nordex and Heidelberger, with negative inputs in the ROA and ROE indexes, although SGL's issues began before the COVID-19 crisis. The company has improved efficiency in generating profit from its assets and equity since 2018, presenting a slack mean of 63.3% combined with a standard deviation of 12.3%. As with Nordex, the combination of strong and solid results also classifies SGL as a benchmark.

Siemens AG was considered a functional benchmark due to its massive market capitalization, larger than all the other companies combined. This significant market presence underscores Siemens AG's substantial influence and stability within the industry, highlighting its capability to leverage economies of scale and achieve competitive advantages in cost management and resource allocation. Additionally, Siemens AG's low standard deviation indicates an elevated level of consistency in its financial and operational performance, suggesting stable performance across various economic conditions. This consistency can be attributed to Siemens AG's robust risk management practices, diversified portfolio, and strategic investments in innovation and technology. Siemens AG's commitment to sustainability and adherence to high corporate governance standards also contributes to its standing as a benchmark, not only for the M&E sector, but for all companies that seek improved ESG results.

Finally, WashTec AG, Varta AG, and Aumann AG were the worst-ranked companies in our research. Despite some good indicators, such as Aumann AG's low standard deviation, their overall returns per DMU were not competitive, serving as clear examples of what not to pursue. For future studies, examining with the RBV theory and Five Forces of Porter framework the reasons of their inferior performance can provide further insights of not ideal business management decisions and inefficient value-creation strategies, both of which should be avoided.

Some honorable mention remarks should also be made about this study:

(i) As shown in 2.1., the M&E sector is undergoing an interesting transformation as ESG demands and requirements grow, increasing companies' costs and initial investments. These heightened barriers to entry and fixed costs impact both new and existing companies. Additionally, regulatory requirements and high-quality standards catalyze this phenomenon, potentially leading to the winning or last surviving companies to be more ESG friendly, benefiting the entire society.

However, pressure from new entrants in developing countries, such as China and other Asian nations, could challenge German companies, potentially leading to a crisis rather than an evolution as previously proposed. Further study is needed to understand if companies from other countries are also adopting and being pressured to meet ESG standards, which is costly. If the answer is no, neither will the society enjoy the benefits of a shift towards an ESG economy, nor will the German M&E companies thrive in the future.

(ii) Further commenting on the research, DEA proved to be the correct choice of analytical framework for this study. DEA allowed the researcher not only to identify the top leading and benchmark companies for the M&E sector, but also to exclude outliers via the Standard Deviation results. The qualitative analysis using RBV and Five forces of Porter demonstrated that the leading firms had a Sustained Competitive Advantage over their competitors, further assessing the validity of the DEA calculation. However, the time horizon from the analysis was a challenge. Due to the Covid-19 outbreak, all companies experienced a crisis in the analyzed period, resulting in negative ROA and ROE for many (like Heidelberger and Nordex). Alternatively, observing which companies did not experience negative results serves as a prof on their stability, reliability, and sustained advantages even in tough times, highlighting attributes such as top risk management, corporate governance efficiency and market and product diversification (as seen in Siemens' case). Still, had the data collected not been normalized to account for negative results, the DEA results would have been unreliable, and the ranking incorrect.

(iii) For further research, it is recommended to choose a longer time horizon for the analysis to provide more extensive periods of observation and to mitigate the impact of occasional crises. DEA can also be used in this case. Furthermore, new studies including more companies from other countries can also be done. The researcher can investigate e.g., the top-performing companies from other developed countries (such as other Europeans nation, US, Canada, and Japan) to test if the German companies are well

performers against the countries' counterparts. Moreover, it is possible to include developing nation companies to test for the hypothesis made previously on commentary (i). An expansion from this research into different sectors, such as oil and gas, automotive, and healthcare, is also recommended to investigate the ESG dynamic in the economy.

(iv) For data collection, Refinitiv Eikon was a powerful and reliable source. The software was easy and intuitive to use, and the results were clear and easy to process, with data export to Excel being straightforward. For the future research mentioned in commentary (iii), Refinitiv can provide the data for both developing and developed countries' companies. Additionally, the researcher can use Refinitiv to also explore and use other Financial and ESG indexes in the DEA analysis, different from the used ROE, ROA, E score, S score and G score.

(v) The Resource-based View (RBV) theory and Porter's Five Forces analysis were essential for the qualitative analysis in this study. The researcher's focus on identifying the forces from all stakeholders provided a clear, fast, and assertive understanding of each company's characteristics. Furthermore, the Porter Framework provided a clear resume and understanding of the competitive dynamics within the M&E industry and its companies, which is crucial for developing effective business plans.

By identifying Barney's (1991) three types of assets and resources that enable value-creation strategies (Physical capital, Human capital, and Organizational capital), differences between companies were clear. These resources, when well deployed, create competitive advantages, which all our identified benchmarks enjoy. The works from Koroleva et al., (2020) and Clarkson et al., (2011) were also used to further emphasize that ESG factors are rare and difficult-to-imitate resources, which can enhance overall cash flow generation and financial performance.

5. CONCLUSION AND FUTURE ANALYSIS

This study further contributes to the DEA literature, by successfully establishing a connection between financial resources and ESG achievements within the German M&E sector using the DEA methodology. Our findings indicate that companies like Heidelberger Druckmaschinen AG, Nordex SE, SGL Carbon SE and Siemens AG lead in efficiently utilizing financial resources to achieve high ESG scores. However, due to high Standard Deviation of results, Heidelberger was excluded from the list of companies that serve as benchmarks for best practices within the industry.

On the other hand, companies like WashTec AG, Varta AG, and Aumann AG were identified as the worst performers in our study. Investigating these companies further could provide valuable insights into common mistakes and strategies to avoid, serving as a benchmark for what not to do in the industry.

A subsequent benchmarking analysis was conducted using Porter's Five Forces framework, Resource-Based View (RBV) Theory, to understand the competitive dynamics of the leading firms. As for another contribution to the DEA literature, the qualitative findings from RBV and Porter matched with the quantitative results from the DEA ranking and financial indicators, indicating that further research can also use this combination to find adequate results. Our study also incorporated both Competitive Benchmarking and Functional Benchmarking methodologies, the first being applied to Nordex SE and SGL Carbon SE and the second to Siemens AG.

Nordex SE, specialized in onshore wind turbines, demonstrated significant ESG achievements despite financial challenges, which can be classified as a Sustained Competitive advantage in ESG value-creation. Similarly, SGL Carbon SE, a leader in carbon-based solutions, exhibited notable improvements in efficiency and ESG performance despite encountering financial difficulties prior to the COVID-19 pandemic.

Siemens AG's substantial market capitalization reflects its ability to leverage economies of scale and achieve competitive advantages. Its low standard deviation indicates consistent financial and ESG performance. Siemens AG's strong commitment to sustainability and corporate governance further establishes it as a benchmark not only for the M&E sector but, also for other companies aiming to improve ESG outcomes.

We hope our methods can be used to establish similar studies in a broader context. For instance, some of the limitations from the research were (i) the time horizon for (ii)

number of analyzed companies. Firstly, because of the Covid-19 outbreak and the short time horizon, all companies experienced a crisis in the analyzed period, resulting in negative ROA and ROE for many. It is recommended that future research incorporates a longer time horizon to mitigate eventual systemic crisis on the analysis. As for (ii), analyzing only the German companies from the machinery and equipment (M&E) sector is not representative for the entire economy, and serves more of a case study. For future analysis, the researcher should consider expanding the study to include companies from various countries and sectors, which would provide a better understanding of the benchmarks in converting financial resources into ESG results.

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APPENDIX 1: LIST OF PUBLIC TRADED GERMAN COMPANIES FROM THE M&E SECTOR

Identifier (RIC)	Company Name	Subsector	Market Cap (USD) (Σ=Avg)	ROE	ROA	ESG Score	Environmental Score	Governance Score	Social Score	ESG Controversies Score
SIEGn.DE	Siemens AG	Electrical Components & Equipment	144.954.826.645	16,4%	5,7%	82.99 (A-)	87.67 (A)	79.22 (A-)	81.59 (A-)	69.12 (B+)
DTGGe.DE	Daimler Truck Holding AG	Heavy Machinery & Vehicles	30.160.914.929	14,9%	4,7%	81.39 (A-)	85.96 (A)	64.92 (B)	89.78 (A)	69.12 (B+)
8TRA.DE	Traton SE	Heavy Machinery & Vehicles	12.444.732.018	15,7%	2,0%	45.40 (C+)	39.02 (C)	49.23 (C+)	48.31 (C+)	100.00 (A+)
KBX.DE	Knorr Bremse AG	Heavy Machinery & Vehicles	10.291.211.043	18,6%	6,7%	79.17 (A-)	76.87 (A-)	64.46 (B)	92.49 (A+)	100.00 (A+)
G1AG.DE	GEA Group AG	Industrial Machinery & Equipment	6.951.024.603	18,6%	6,4%	79.33 (A-)	85.29 (A)	57.63 (B-)	90.42 (A)	100.00 (A+)
KGX.DE	Kion Group AG	Heavy Machinery & Vehicles	6.090.910.982	4,5%	0,7%	71.90 (B+)	63.09 (B)	78.81 (A-)	74.68 (B+)	100.00 (A+)
OSRn.H	Osram Licht AG	Electrical Components & Equipment	5.305.599.223	-27,6%	-6,4%	81.11 (A-)	63.60 (B)	83.39 (A)	95.40 (A+)	63.46 (B)
KRNG.DE	Krones AG	Industrial Machinery & Equipment	3.967.209.707	14,5%	4,9%	47.95 (C+)	35.21 (C)	31.39 (C-)	72.23 (B+)	100.00 (A+)
GILG.DE	DMG Mori AG	Industrial Machinery & Equipment	3.753.278.615	8,8%	5,7%	49.69 (C+)	43.68 (C+)	39.16 (C)	63.23 (B)	100.00 (A+)
NDXG.DE	Nordex SE	Heavy Eletrical Equipment	2.401.033.279	-48,2%	-11,2%	78.06 (A-)	63.03 (B)	82.35 (A-)	88.54 (A)	69.12 (B+)
STM1.DE	Stabilus SE	Industrial Machinery & Equipment	1.758.007.117	14,9%	7,9%	62.78 (B)	63.72 (B)	51.84 (B-)	70.25 (B+)	100.00 (A+)
PV.DE	Pfeiffer Vacuum Technology AG	Industrial Machinery & Equipment	1.667.156.860	14,5%	11,0%	54.80 (B-)	24.01 (D+)	82.96 (A-)	61.52 (B)	100.00 (A+)
JUNG_p.DE	Jungheinrich AG	Heavy Machinery & Vehicles	1.658.465.519	16,3%	4,5%	52.97 (B-)	47.69 (C+)	42.85 (C+)	65.52 (B)	100.00 (A+)

DUE G.D E	Duerr AG	Industrial Machinery & Equipment	1.604.0 49.126	14 ,2 %	3, 1 %	59.9 7 (B)	48.73 (C+)	61.1 3 (B)	69.3 7 (B+)	100.0 0 (A+)
WA CGn. DE	Wacker Neuson SE	Heavy Machinery & Vehicles	1.346.6 90.440	14 ,7 %	6, 1 %	63.4 6 (B)	63.47 (B)	68.7 6 (B+)	59.4 1 (B)	100.0 0 (A+)
KSB G.D E	KSB SE & Co KGaA	Industrial Machinery & Equipment	1.171.5 31.063			54.1 4 (B-)	56.01 (B-)	42.7 5 (C+)	61.1 2 (B)	69.12 (B+)
SGC G.D E	SGL Carbon SE	Electrical Components & Equipment	788.08 5.603	10 ,6 %	8, 8 %	70.9 6 (B+)	71.67 (B+)	86.5 3 (A)	58.4 3 (B)	100.0 0 (A+)
DEZ G.D E	DEUTZ AG	Heavy Machinery & Vehicles	787.22 8.497	14 ,6 %	5, 8 %	67.0 2 (B+)	60.95 (B)	58.6 7 (B)	78.9 6 (A-)	100.0 0 (A+)
VAR 1.DE	Varta AG	Electrical Components & Equipment	726.09 9.668		- 15 ,9 %	48.9 1 (C+)	42.57 (C+)	27.8 1 (C-)	70.8 2 (B+)	100.0 0 (A+)
CEV G.H	Centrotec SE	Electrical Components & Equipment	656.05 3.253	11 ,4 %	0, 4 %					
HG1 G.F	Homag Group AG	Industrial Machinery & Equipment	639.49 7.897	60 ,5 %	23 ,1 %					
NOE J.DE	Norma Group SE	Industrial Machinery & Equipment	518.84 2.058	3, 9 %	2, 6 %	81.5 3 (A-)	74.67 (B+)	89.8 1 (A)	81.5 0 (A-)	100.0 0 (A+)
WS UG. DE	WashTec AG	Industrial Machinery & Equipment	482.32 8.308	36 ,9 %	9, 6 %	55.4 6 (B-)	72.47 (B+)	57.3 3 (B-)	38.4 8 (C)	100.0 0 (A+)
2GB G.D E	2G Energy AG	Heavy Eletrical Equipment	454.45 3.734			30.7 5 (C-)	18.20 (D+)	10.7 1 (D)	57.5 3 (B-)	100.0 0 (A+)
VQT G.H	va Q tec AG	Industrial Machinery & Equipment	382.71 7.378	- 38 ,8 %	- 8, 1 %	37.7 1 (C)	20.38 (D+)	34.3 9 (C)	56.1 0 (B-)	100.0 0 (A+)
HDD G.D E	Heidelber ger Druckma schinen AG	Industrial Machinery & Equipment	362.14 8.211	15 ,4 %	4, 2 %	69.8 9 (B+)	64.94 (B)	81.0 6 (A-)	65.8 9 (B)	100.0 0 (A+)
CEA G.D E	Friwo AG	Electrical Components & Equipment	292.03 5.328	- 9, 2 %	0, 6 %					
MX HNn. DE	MAX Automati on SE	Industrial Machinery & Equipment	279.31 3.250	28 ,9 %	4, 6 %	22.8 8 (D+)	36.81 (C)	9.72 (D)	20.1 7 (D+)	100.0 0 (A+)
AAG G.D E	Aumann AG	Industrial Machinery & Equipment	259.84 0.397	3, 8 %	0, 3 %	27.0 7 (C-)	40.74 (C)	15.3 1 (D)	23.5 2 (D+)	100.0 0 (A+)

MBHG_p. F	Maschinenfabrik Berthold Hermle AG	Industrial Machinery & Equipment	217.836.730	25,2%	16,3%	18.10 (D+)	12.89 (D)	4.98 (D-)	32.89 (C-)	100.00 (A+)
GSC1n.DE	Gesco SE	Industrial Machinery & Equipment	198.718.304	9,4%	7,9%	47.80 (C+)	19.16 (D+)	87.75 (A)	43.55 (C+)	100.00 (A+)
SKBG.DE	Koenig & Bauer AG	Industrial Machinery & Equipment	195.108.822	2,4%	0,8%	39.50 (C)	21.22 (D+)	63.11 (B)	38.21 (C)	100.00 (A+)
RSL2.DE	R Stahl AG	Electrical Components & Equipment	145.842.769	19,5%	0,8%	24.91 (D+)	9.88 (D)	25.49 (C-)	38.23 (C)	100.00 (A+)
TTRGn.DE	technotrans SE	Industrial Machinery & Equipment	140.437.856	8,4%	5,7%	26.91 (C-)	16.02 (D)	28.65 (C-)	35.54 (C)	100.00 (A+)
HNLG.DE	Dr Hoenle AG	Industrial Machinery & Equipment	109.188.969			19.42 (D+)	13.84 (D)	11.67 (D)	30.44 (C-)	100.00 (A+)
HP3An.DE	Ringmetall SE	Industrial Machinery & Equipment	99.236.549	8,7%	12,5%	23.85 (D+)	15.03 (D)	16.87 (D+)	37.25 (C)	100.00 (A+)
KWGG.DE	KHD Humboldt Wedag International AG	Industrial Machinery & Equipment	91.864.528	2,9%	0,1%	35.93 (C)	44.88 (C+)	41.38 (C)	23.59 (D+)	100.00 (A+)
MZXG.DE	Masterflex SE	Industrial Machinery & Equipment	91.185.114	14,1%	9,2%	30.76 (C-)	11.71 (D)	43.35 (C+)	38.61 (C)	100.00 (A+)
V6CG.DE	Viscom AG	Industrial Machinery & Equipment	74.039.726	9,1%	5,0%	32.51 (C-)	14.19 (D)	49.87 (C+)	36.03 (C)	100.00 (A+)
KGRG.F	Lewag Holding AG	Industrial Machinery & Equipment	64.056.940	-5,2%	-6,8%					
ALXA.F	Alexanderwerk AG	Industrial Machinery & Equipment	59.010.029	35,1%	13,0%					
CY1k.F	Sbf AG	Electrical Components & Equipment	43.544.424	-5,0%	-1,4%					
DARG.DE	Datron AG	Industrial Machinery & Equipment	43.488.188	12,1%	9,6%					
VBX.DE	Voltabox AG	Electrical Components & Equipment	26.328.068	-313,3%	-64,2%					

CFC G.D E	UET United Electronic Technology AG	Electrical Components & Equipment	23.994.824	132,2 %	-2,4 %					
IS7. DE	InTiCa Systems SE	Electrical Components & Equipment	23.808.962	-1,1 %	2,6 %	30.04 (C-)	42.60 (C+)	29.46 (C-)	18.99 (D+)	100.00 (A+)
NUC G.S G	Nucletron Electronic AG	Electrical Components & Equipment	23.588.771	10,6 %	8,2 %					
286n .MU	NCTE AG	Industrial Machinery & Equipment	19.791.251							
SNG Gk.D E	Singulus Technologies AG	Industrial Machinery & Equipment	15.040.498		-0,1 %					
SCM G.D	Schumag AG	Industrial Machinery & Equipment	13.102.552	-197,9 %	-6,4 %					
ETE G.D	Ekotechnika AG	Heavy Machinery & Vehicles	11.949.531	46,9 %	15,1 %	3.23 (D-)		2.89 (D-)	6.45 (D-)	100.00 (A+)
PIT G.F	Pittler Maschinenfabrik AG	Industrial Machinery & Equipment	6.082.065	19,7 %	13,6 %					
C0M .F	CCS Abwicklungs AG	Electrical Components & Equipment	2.132.229	-218,5 %	-102,3 %					
N2F 0k.M U	NanoFocus AG	Industrial Machinery & Equipment	1.706.934	-22,9 %	-7,3 %					
KF W1. BE	Klepper Faltbootwerft AG	Shipbuilding	276.435							
DOR G.D	Dorstener Maschinenfabrik AG	Industrial Machinery & Equipment	18.872							

Source: Refinitiv, 2023

APPENDIX 2: NORMALIZED DEA DATA

Company	Year	DMU	ROA	ROE	E	S	G
AAGG.DE	2018	AAGG.DE_2018	0,705225	0,825035	0,388255	0,017282	0
AAGG.DE	2019	AAGG.DE_2019	0,633405	0,797227	0,409889	0,000887	0,026071
AAGG.DE	2020	AAGG.DE_2020	0,327755	0,697689	0,429366	0,006897	0,197936
AAGG.DE	2021	AAGG.DE_2021	0,454955	0,738593	0,42965	0	0,325816
AAGG.DE	2022	AAGG.DE_2022	0,534818	0,763962	0,46567	0,188697	0,400228
DEZG.DE	2018	DEZG.DE_2018	0,712282	0,838	0,654902	0,869853	0,265202
DEZG.DE	2019	DEZG.DE_2019	0,659227	0,815371	0,691842	0,806623	0,232792
DEZG.DE	2020	DEZG.DE_2020	0,238534	0,639539	0,72491	0,802441	0,619378
DEZG.DE	2021	DEZG.DE_2021	0,626001	0,805842	0,719467	0,807418	0,721879
DEZG.DE	2022	DEZG.DE_2022	0,715183	0,845589	0,696821	0,843834	0,756816
DUEG.DE	2018	DUEG.DE_2018	0,675295	0,872943	0,395876	0,420732	0,30613
DUEG.DE	2019	DUEG.DE_2019	0,638225	0,84291	0,435038	0,467413	0,365637
DUEG.DE	2020	DUEG.DE_2020	0,51238	0,749566	0,503933	0,654222	0,654762
DUEG.DE	2021	DUEG.DE_2021	0,593807	0,818674	0,528105	0,727453	0,793404
DUEG.DE	2022	DUEG.DE_2022	0,625984	0,842985	0,5554	0,691553	0,790423
G1AG.DE	2018	G1AG.DE_2018	0,590296	0,791479	0,763972	0,745354	0,708844
G1AG.DE	2019	G1AG.DE_2019	0,416628	0,705654	0,784305	0,712982	0,691631
G1AG.DE	2020	G1AG.DE_2020	0,586568	0,796402	0,789544	0,741027	0,682165
G1AG.DE	2021	G1AG.DE_2021	0,694815	0,860467	0,772706	0,785599	0,697823
G1AG.DE	2022	G1AG.DE_2022	0,733598	0,875343	0,974391	0,977975	0,747889
GILG.DE	2018	GILG.DE_2018	0,73454	0,84448	0,356425	0,450044	0,258898
GILG.DE	2019	GILG.DE_2019	0,731349	0,842835	0,393258	0,443022	0,257489
GILG.DE	2020	GILG.DE_2020	0,597799	0,788026	0,419151	0,609169	0,616653
GILG.DE	2021	GILG.DE_2021	0,642873	0,803164	0,540846	0,624617	0,67836
GILG.DE	2022	GILG.DE_2022	0,71183	0,829992	0,499816	0,657823	0,627782
HDDG.DE	2018	HDDG.DE_2018	0,544117	0,787049	0,632299	0,473326	0,568293
HDDG.DE	2019	HDDG.DE_2019	0,554142	0,798095	0,619632	0,530154	0,527502
HDDG.DE	2020	HDDG.DE_2020	0,065969	0	0,653111	0,530654	0,638526
HDDG.DE	2021	HDDG.DE_2021	0,464936	0,576733	0,63019	0,457602	0,681556
HDDG.DE	2022	HDDG.DE_2022	0,574186	0,886124	0,65143	0,44926	0,633374
JUNG_p.DE	2018	JUNG_p.DE_2018	0,65463	0,850478	0,389669	0,453211	0,441276
JUNG_p.DE	2019	JUNG_p.DE_2019	0,640865	0,843373	0,452259	0,638092	0,400178
JUNG_p.DE	2020	JUNG_p.DE_2020	0,61747	0,827	0,474323	0,620769	0,617219
JUNG_p.DE	2021	JUNG_p.DE_2021	0,681693	0,866591	0,428133	0,630353	0,622108
JUNG_p.DE	2022	JUNG_p.DE_2022	0,672958	0,85369	0,544231	0,687459	0,645442
KBX.DE	2018	KBX.DE_2018	0,869976	0,9966	0,858883	0,775997	0,335466
KBX.DE	2019	KBX.DE_2019	0,841743	0,999382	0,859255	0,825689	0,492298
KBX.DE	2020	KBX.DE_2020	0,770386	0,943357	0,903287	0,921182	0,711668
KBX.DE	2021	KBX.DE_2021	0,816453	0,959801	0,893059	0,977747	0,824634
KBX.DE	2022	KBX.DE_2022	0,74339	0,893537	0,879644	1	0,806865
KGX.DE	2018	KGX.DE_2018	0,628686	0,845306	0,528257	0,731712	0,762924
KGX.DE	2019	KGX.DE_2019	0,633748	0,84881	0,532943	0,691485	0,821975

KGX.DE	2020	KGX.DE_2020	0,574084	0,797059	0,757421	0,883967	0,935264
KGX.DE	2021	KGX.DE_2021	0,649258	0,840618	0,714172	0,805748	0,920522
KGX.DE	2022	KGX.DE_2022	0,545672	0,772594	0,715001	0,794857	0,914425
NDXG.DE	2018	NDXG.DE_2018	0,429984	0,691247	0,644475	0,507358	0,412132
NDXG.DE	2019	NDXG.DE_2019	0,456447	0,693353	0,637965	0,496125	0,513548
NDXG.DE	2020	NDXG.DE_2020	0,422585	0,646531	0,700356	0,873283	0,810135
NDXG.DE	2021	NDXG.DE_2021	0,346149	0,5932	0,729511	0,934988	0,900537
NDXG.DE	2022	NDXG.DE_2022	0,15424	0,4182	0,712777	0,95506	0,929304
NOEJ.DE	2018	NOEJ.DE_2018	0,741355	0,868703	0,753842	0,812206	0,880512
NOEJ.DE	2019	NOEJ.DE_2019	0,65309	0,823919	0,890284	0,818848	0,947881
NOEJ.DE	2020	NOEJ.DE_2020	0,536465	0,766686	0,900539	0,891071	0,971369
NOEJ.DE	2021	NOEJ.DE_2021	0,650955	0,819817	0,873264	0,877986	0,976958
NOEJ.DE	2022	NOEJ.DE_2022	0,608511	0,798429	0,859712	0,872968	1
PV.DE	2018	PV.DE_2018	0,909478	0,893059	0	0,170403	0,299292
PV.DE	2019	PV.DE_2019	0,772289	0,84474	0,182554	0,312136	0,643073
PV.DE	2020	PV.DE_2020	0,681632	0,814155	0,197639	0,478019	0,821791
PV.DE	2021	PV.DE_2021	0,822262	0,857649	0,242522	0,64033	0,957668
PV.DE	2022	PV.DE_2022	0,886093	0,876768	0,279595	0,640973	0,920216
SGCG.DE	2018	SGCG.DE_2018	0,63096	0,82836	0,796969	0,700745	0,713018
SGCG.DE	2019	SGCG.DE_2019	0,333553	0,634231	0,791243	0,685975	0,770122
SGCG.DE	2020	SGCG.DE_2020	0,214036	0,483092	0,838699	0,636889	0,847396
SGCG.DE	2021	SGCG.DE_2021	0,713888	0,930356	0,806184	0,640904	0,906244
SGCG.DE	2022	SGCG.DE_2022	0,814477	0,93832	0,797829	0,603969	0,948208
SIEGn.DE	2018	SIEGn.DE_2018	0,657344	0,839457	0,959665	0,849551	0,918649
SIEGn.DE	2019	SIEGn.DE_2019	0,641651	0,827243	0,968142	0,844896	0,977758
SIEGn.DE	2020	SIEGn.DE_2020	0,624011	0,8234	0,992467	0,870021	0,991567
SIEGn.DE	2021	SIEGn.DE_2021	0,665144	0,844935	0,998549	0,869792	0,967088
SIEGn.DE	2022	SIEGn.DE_2022	0,624088	0,814155	1	0,870859	0,928829
SKBG.DE	2018	SKBG.DE_2018	0,704147	0,857594	0,254144	0,318596	0,228879
SKBG.DE	2019	SKBG.DE_2019	0,657059	0,83895	0,236965	0,283919	0,549651
SKBG.DE	2020	SKBG.DE_2020	0,275815	0,581332	0,241031	0,278508	0,738495
SKBG.DE	2021	SKBG.DE_2021	0,560747	0,786257	0,256481	0,377471	0,842424
SKBG.DE	2022	SKBG.DE_2022	0,550854	0,778054	0,247363	0,363906	0,786521
VAR1.DE	2018	VAR1.DE_2018	0,755083	0,829613	0,12728	0,160566	0,013022
VAR1.DE	2019	VAR1.DE_2019	0,834674	0,860437	0,182462	0,112383	0,018165
VAR1.DE	2020	VAR1.DE_2020	0,875308	0,899855	0,347202	0,277207	0,334687
VAR1.DE	2021	VAR1.DE_2021	0,872302	0,923439	0,397844	0,588591	0,53649
VAR1.DE	2022	VAR1.DE_2022	0	0,414055	0,485934	0,748509	0,521093
WACGn.DE	2018	WACGn.DE_2018	0,793981	0,843058	0,155592	0,120559	0,119989
WACGn.DE	2019	WACGn.DE_2019	0,665965	0,80874	0,195314	0,393567	0,307332
WACGn.DE	2020	WACGn.DE_2020	0,545631	0,768172	0,597421	0,471888	0,604341
WACGn.DE	2021	WACGn.DE_2021	0,728393	0,833944	0,669936	0,512518	0,670634
WACGn.DE	2022	WACGn.DE_2022	0,726392	0,831449	0,727953	0,613396	0,823385
WSUG.DE	2018	WSUG.DE_2018	1	1	0,137481	0,103173	0,266379

WSUG.DE	2019	WSUG.DE_2019	0,810325	0,925523	0,206575	0,166433	0,229608
WSUG.DE	2020	WSUG.DE_2020	0,693006	0,85868	0,231493	0,164353	0,747218
WSUG.DE	2021	WSUG.DE_2021	0,924781	0,973451	0,383471	0,310451	0,766676
WSUG.DE	2022	WSUG.DE_2022	0,838941	0,948953	0,822559	0,367661	0,73705

APPENDIX 3: RAW DEA DATA

Company	Year	DMU	ROA	ROE	E	S	G
AAGG.DE	2018	AAGG.DE_2018	5,50	9,68	34,25	9,72	2,41
AAGG.DE	2019	AAGG.DE_2019	3,32	5,51	36,16	8,34	4,79
AAGG.DE	2020	AAGG.DE_2020	-5,96	-9,41	37,87	8,84	20,48
AAGG.DE	2021	AAGG.DE_2021	-2,10	-3,28	37,90	8,26	32,15
AAGG.DE	2022	AAGG.DE_2022	0,32	0,52	41,08	24,20	38,94
DEZG.DE	2018	DEZG.DE_2018	5,71	11,62	57,77	81,72	26,62
DEZG.DE	2019	DEZG.DE_2019	4,10	8,23	61,03	76,38	23,66
DEZG.DE	2020	DEZG.DE_2020	-8,67	-18,13	63,94	76,02	58,95
DEZG.DE	2021	DEZG.DE_2021	3,09	6,80	63,46	76,44	68,31
DEZG.DE	2022	DEZG.DE_2022	5,80	12,76	61,46	79,52	71,50
DUEG.DE	2018	DUEG.DE_2018	4,59	16,86	34,92	43,79	30,35
DUEG.DE	2019	DUEG.DE_2019	3,46	12,36	38,37	47,73	35,79
DUEG.DE	2020	DUEG.DE_2020	-0,36	-1,63	44,45	63,51	62,18
DUEG.DE	2021	DUEG.DE_2021	2,11	8,72	46,58	69,69	74,84
DUEG.DE	2022	DUEG.DE_2022	3,09	12,37	48,99	66,66	74,56
G1AG.DE	2018	G1AG.DE_2018	2,01	4,65	67,39	71,20	67,12
G1AG.DE	2019	G1AG.DE_2019	-3,26	-8,22	69,18	68,47	65,55
G1AG.DE	2020	G1AG.DE_2020	1,90	5,39	69,64	70,84	64,68
G1AG.DE	2021	G1AG.DE_2021	5,18	14,99	68,16	74,60	66,11
G1AG.DE	2022	G1AG.DE_2022	6,36	17,22	85,95	90,85	70,68
GILG.DE	2018	GILG.DE_2018	6,39	12,59	31,44	46,27	26,04
GILG.DE	2019	GILG.DE_2019	6,29	12,35	34,69	45,67	25,91
GILG.DE	2020	GILG.DE_2020	2,24	4,13	36,97	59,70	58,70
GILG.DE	2021	GILG.DE_2021	3,60	6,40	47,71	61,01	64,33
GILG.DE	2022	GILG.DE_2022	5,70	10,42	44,09	63,81	59,72
HDDG.DE	2018	HDDG.DE_2018	0,61	3,98	55,77	48,23	54,29
HDDG.DE	2019	HDDG.DE_2019	0,91	5,64	54,66	53,03	50,56
HDDG.DE	2020	HDDG.DE_2020	-13,91	-113,99	57,61	53,07	60,70
HDDG.DE	2021	HDDG.DE_2021	-1,80	-27,54	55,59	46,90	64,63
HDDG.DE	2022	HDDG.DE_2022	1,52	18,83	57,46	46,20	60,23
JUNG_p.DE	2018	JUNG_p.DE_2018	3,96	13,49	34,37	46,53	42,69
JUNG_p.DE	2019	JUNG_p.DE_2019	3,54	12,43	39,89	62,15	38,94
JUNG_p.DE	2020	JUNG_p.DE_2020	2,83	9,97	41,84	60,68	58,75
JUNG_p.DE	2021	JUNG_p.DE_2021	4,78	15,91	37,76	61,49	59,20
JUNG_p.DE	2022	JUNG_p.DE_2022	4,52	13,97	48,01	66,31	61,33
KBX.DE	2018	KBX.DE_2018	10,50	35,39	75,76	73,79	33,03
KBX.DE	2019	KBX.DE_2019	9,64	35,81	75,79	77,99	47,35

KBX.DE	2020	KBX.DE_2020	7,48	27,41	79,68	86,05	67,38
KBX.DE	2021	KBX.DE_2021	8,87	29,88	78,77	90,83	77,69
KBX.DE	2022	KBX.DE_2022	6,66	19,95	77,59	92,71	76,07
KGX.DE	2018	KGX.DE_2018	3,17	12,72	46,60	70,05	72,05
KGX.DE	2019	KGX.DE_2019	3,33	13,24	47,01	66,65	77,45
KGX.DE	2020	KGX.DE_2020	1,52	5,48	66,81	82,91	87,79
KGX.DE	2021	KGX.DE_2021	3,80	12,01	63,00	76,30	86,44
KGX.DE	2022	KGX.DE_2022	0,65	1,82	63,07	75,38	85,88
NDXG.DE	2018	NDXG.DE_2018	-2,86	-10,38	56,85	51,11	40,03
NDXG.DE	2019	NDXG.DE_2019	-2,06	-10,06	56,27	50,16	49,29
NDXG.DE	2020	NDXG.DE_2020	-3,08	-17,08	61,78	82,01	76,36
NDXG.DE	2021	NDXG.DE_2021	-5,40	-25,07	64,35	87,22	84,62
NDXG.DE	2022	NDXG.DE_2022	-11,23	-51,30	62,87	88,91	87,24
NOEJ.DE	2018	NOEJ.DE_2018	6,59	16,22	66,49	76,85	82,79
NOEJ.DE	2019	NOEJ.DE_2019	3,91	9,51	78,53	77,41	88,94
NOEJ.DE	2020	NOEJ.DE_2020	0,37	0,93	79,43	83,51	91,08
NOEJ.DE	2021	NOEJ.DE_2021	3,85	8,90	77,03	82,40	91,59
NOEJ.DE	2022	NOEJ.DE_2022	2,56	5,69	75,83	81,98	93,70
PV.DE	2018	PV.DE_2018	11,70	19,87	0,00	22,65	29,73
PV.DE	2019	PV.DE_2019	7,53	12,63	16,10	34,62	61,11
PV.DE	2020	PV.DE_2020	4,78	8,05	17,43	48,63	77,43
PV.DE	2021	PV.DE_2021	9,05	14,57	21,39	62,33	89,83
PV.DE	2022	PV.DE_2022	10,99	17,43	24,66	62,39	86,41
SGCG.DE	2018	SGCG.DE_2018	3,24	10,18	70,30	67,44	67,50
SGCG.DE	2019	SGCG.DE_2019	-5,79	-18,92	69,79	66,19	72,71
SGCG.DE	2020	SGCG.DE_2020	-9,42	-41,58	73,98	62,04	79,77
SGCG.DE	2021	SGCG.DE_2021	5,76	25,46	71,11	62,38	85,14
SGCG.DE	2022	SGCG.DE_2022	8,81	26,66	70,37	59,26	88,97
SIEGn.DE	2018	SIEGn.DE_2018	4,04	11,84	84,65	80,00	86,27
SIEGn.DE	2019	SIEGn.DE_2019	3,57	10,01	85,40	79,61	91,67
SIEGn.DE	2020	SIEGn.DE_2020	3,03	9,43	87,54	81,73	92,93
SIEGn.DE	2021	SIEGn.DE_2021	4,28	12,66	88,08	81,71	90,69
SIEGn.DE	2022	SIEGn.DE_2022	3,03	8,05	88,21	81,80	87,20
SKBG.DE	2018	SKBG.DE_2018	5,46	14,56	22,42	35,17	23,30
SKBG.DE	2019	SKBG.DE_2019	4,04	11,76	20,90	32,24	52,59
SKBG.DE	2020	SKBG.DE_2020	-7,54	-26,85	21,26	31,78	69,82
SKBG.DE	2021	SKBG.DE_2021	1,11	3,87	22,62	40,14	79,31
SKBG.DE	2022	SKBG.DE_2022	0,81	2,64	21,82	38,99	74,21
VAR1.DE	2018	VAR1.DE_2018	7,01	10,36	11,23	21,82	3,60
VAR1.DE	2019	VAR1.DE_2019	9,43	14,98	16,09	17,75	4,07
VAR1.DE	2020	VAR1.DE_2020	10,66	20,89	30,63	31,67	32,96
VAR1.DE	2021	VAR1.DE_2021	10,57	24,43	35,09	57,97	51,38
VAR1.DE	2022	VAR1.DE_2022	-15,91	-51,92	42,86	71,47	49,98
WACGn.DE	2018	WACGn.DE_2018	8,19	12,38	13,72	18,44	13,36

WACGn.DE	2019	WACGn.DE_2019	4,31	7,24	17,23	41,50	30,46
WACGn.DE	2020	WACGn.DE_2020	0,65	1,15	52,70	48,11	57,58
WACGn.DE	2021	WACGn.DE_2021	6,20	11,01	59,09	51,54	63,63
WACGn.DE	2022	WACGn.DE_2022	6,14	10,64	64,21	60,06	77,57
WSUG.DE	2018	WSUG.DE_2018	14,45	35,90	12,13	16,97	26,73
WSUG.DE	2019	WSUG.DE_2019	8,69	24,74	18,22	22,32	23,37
WSUG.DE	2020	WSUG.DE_2020	5,13	14,72	20,42	22,14	70,62
WSUG.DE	2021	WSUG.DE_2021	12,16	31,92	33,83	34,48	72,40
WSUG.DE	2022	WSUG.DE_2022	9,56	28,25	72,56	39,31	69,69