Environmental Sustainability Index: Enabling comparison of companies on relevant indicators of sustainability

Masterthesis

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Abstract

This paper provides a helpful solution towards solving the most important issues regarding quantifying environmental sustainability of companies. The provided solution is presented on a use-case on companies from the industrial sector from the Netherlands, but is applicable to companies within various other sectors. The build up of the proposed solution is provided in a transparent manner, so that further, deepend research can be used to upgrade the quantification method. A lack of comparability, as well as a lack of transparency, due to different, not standardized rating methods, a lack of trustworthiness, and high subjectivity are described as the most important issues of quantifying environmental sustainability of companies. These issues have to be tackled, to create a better understanding of the current state of environmental impact, as well as the progress towards minimizing this impact. Environmental sustainability is becoming increasingly relevant, not only because of the current problem of climate change, but also because of the high demand by different stakeholders to tackle this problem. To tackle the current issues of quantifying environmental sustainability, this solution is based on carefully selected indicators from scientific literature, existing frameworks, and environmental laws. Following up, the values of these indicators were normalized onto a unified scale and then aggregated together, to create a single index, representing the current state of environmental sustainability.

This method offers a standardized procedure to assess environmental sustainability of companies, as well as offers progress in the scientific field of quantifying environmental sustainability within a single value.

Abbreviations

ESI - Environmental Sustainability Index
TBL - Triple Bottom Line
GRI - Global Reporting Initiative
EU - European Union
UN - United Nations
CSRD - Corporate Social Reporting Directive
IT - Information Technologies
NGO - Non Government Organisation
WCED - World Commission on Environment and Development
SDG - Sustainable Development Goals
KPI - key Performance Indicator
IoT - Internet of Things
AI - Artificial Intelligence
BDA - Big Data Analytics
NOx - Nitrogen Oxides
SOx - Sulfur Oxides
CO2 - Carbon Dioxide
DSRM - Design Science Research Methodology
DSR - Design Science Research
CDP - Carbon Disclosure Project
MSCI - Morgan Stanley International Index

1. Introduction

Global warming and climate change have become familiar to many people as some of the most important environmental issues of our time (Houghton, 2005). International organizations and national governments around the globe and within the European Union (EU) acknowledge this rising problem and are therefore major drivers in leading to more sustainable development. To tackle the problems of global warming and climate change, the causes leading to these need to be discovered, analyzed and measured, as well as the progress that tries to counteract this. This research tackles the problem of measuring the process of companies within the EU, reducing their impact onto the environment. Therefore a service on the basis of an index, consisting of multiple indicators was created, to measure the environmental sustainability of companies within the European market and their sustainable development over time. The conducted research was tested in a use case on an industrial company and later on large-cap companies from the Netherlands, to build an index. Although applied to these dutch organizations, the formula should be applicable to companies within the EU.

On the one hand this is relevant, considering about 40% of listed companies produce about 80% of greenhouse gas emissions, of which the industrial sector plays a major role (European Commission, 2022). By addressing this large sector, a lot of gains can be achieved in measuring their current environmental state. This offers the opportunity to see where and how to address weaknesses. On the other hand, this research offers a scientific contribution in quantifying the environmental sustainability within a single value, by developing a composite index for companies, covering a range of important indicators.

To measure sustainability, descriptive data about the current and past state regarding environmental sustainability of companies has to be collected and analyzed. This data should be available in numerical values, to have a quantifiable, comparable variable over time and against other values. Companies therefore need to provide this data, or make it accessible to make an analysis regarding environmental sustainability possible. Regarding the disclosure of non-financial related company data, the EU released in 2014 the directive 2014/95/EU. This directive lays down the rules on the disclosure of non-financial and diversity information by large companies, covering also the environmental branch. This directive has been updated multiple times in the following years (now Corporate Social Reporting Directive - CSRD), so that it is not only restricted to companies with a large capitalization (Cardoni et al., 2019).

To be able to analyze data in any form, information technologies (IT) can play a significant role. Large amounts of data can be analyzed with little time and high accuracy and can even make predictions about the future. This is also the case within the environmental sustainability topic, since more and more data becomes available as companies are required to report their data. Therefore, companies with the analytical skills and the technological capabilities can play a major role in assessing the past and current state of companies' progress and guide towards a more sustainable way of doing business. The problem here is that many companies are still lacking the technical capabilities or do not have the analytical know-how to create value from their measurements. Here, data driven companies, such as Little Rocket, are offered a lot of potential to create a way of doing business by helping other companies to measure their environmental impact, create insights and therefore value from the measurements.

Acknowledging the rising importance of disclosing sustainability data, more and more enterprises are disclosing their non-financial information either on their own, or alongside guidance of one of the many rating agencies or available methodologies. Even though the amount of company disclosures increased, many investors and other stakeholders seem dissatisfied with the amount of different rating schemes and them not being transparent, as well as not being standardized (Keller, 2015). This is also supported by academic studies. These claim that the largest challenge for investors in integrating sustainability information into their investment process is the lack of cross-comparability due to the absence of a standard (Cardoni et al., 2019).
But how do enterprises, investors, or customers know if the right information is displayed or what the right information actually entails?
This question currently states a key problem in the field of disclosing non-financial company information.
Several studies have found that there is no universal environmental performance ranking system and that scores differ by the individual rating agencies (Muñoz-Torres et al., 2018). Another important difficulty, when assessing environmental sustainability, lies in information asymmetries. Consumers, investors, and other stakeholders are not able to verify the sustainability claims made by companies, because they do not have access to the relevant information (Windolph, 2011). Because of this missing transparency companies sometimes choose criteria to their advantage to boost their sustainability scores (Diouf & Boiral, 2017 & Chen & Xie, 2022). This process is labeled as “greenwashing” in this field.
Additionally, due to the increased number of rating agencies, the amount of available rating methodologies increased as well (Keller, 2015). On the one hand are rating agencies working with the provided data from companies. On the other hand do rating agencies, due to the absence of a unified methodology, provide their individual scores and frameworks built on different indicators (Keller, 2015 & Salvado et al., 2015), which makes it difficult to evaluate if their results are good or bad (Rusche et al., 2021).
Since a concrete measurement of company values in comparison with sustainability goals is still missing (Rusche et al., 2021), this paper tries to address this problem by developing a transparent sustainability score. This score is based on carefully selected indicators for the EU, tested on the industrial sector of the Netherlands. The selected indicators were split into the four clusters of emissions, energy, waste, and water. Many of the most cited indicators are inherent in these clusters.
The lack of trust, comparability, and transparency make up some of the biggest problems for disclosing environmental sustainability data.
To raise trust in the disclosure of sustainability data, a simple and comparable way needs to be developed, to raise acceptance regarding the disclosure of companies and precisely show the current state of the problem.
The approach within this research, to get to a desired, trusted, and unified accepted sustainability disclosure, is following the common approach of the concept of composite indexes. To create a composite index a design science research procedure was used. Within this iterative procedure, scientific literature and existing frameworks were analyzed to derive the most mentioned indicators to build the index on. The approach of creating a composite index is based on the mathematical aggregation of several environmental indicators (Zhou et al., 2012). This disclosure has to be done by validated third parties to confirm that the disclosed non-financial data, on which this composite index is built, is trustworthy and valid.
Using this approach of building a composite index on the basis of environmental sustainability indicators, data analysis tools can be of added value.

With more and more companies disclosing their environmental data, large amounts of now available data can be analyzed to disclose correlations, thresholds, and make predictions for future plans to tackle environmental sustainability and therefore climate change. In addition to that, with a diverse variety of data sets available, including an increasing number of open data sets provided by governments, non-governmental organizations (NGOs), and companies, comparing and aggregating data can provide a more comprehensive understanding of the current situation. This allows for more detailed information to be presented than ever before. This research tries to grab the potential of quantifying environmental sustainability, so that stakeholders from different backgrounds are able to interpret the result, as well as compare it against competitors, and their own past results. Furthermore allows such a quantification to measure the progress of companies against set goals by governments and other institutions, or stakeholders.
Based on this opened potential the following research question was developed:

Can a unified sustainability index, based on indicators from scientific literature, contribute to offering a solution to current issues with environmental sustainability ratings, in terms of comparability and trustworthiness, for companies within the European area?

The goal of this research is to provide a comparable rating for the environmental sustainability of European companies, that represents their current state, is transparent, covers the most important indicators, and is simple to understand by stakeholders of any background.
This environmental sustainability rating can, on the one hand be used as a service and an additional revenue stream by Little Rocket, a data analytics company from Enschede, Netherlands, for which this rating was designed. With this service, Little Rocket will be able to analyze descriptive environmental company data and therefore create insights and, based on this, a rating of the current environmental state of the company. On the other hand, it could be possible to make predictions about future developments. Using past data as a basis and therefore help companies guide them to more sustainable development in the future to fulfill the set goals by the EU. With new legislation coming into play from 2023 on, a lot of companies will have to start reporting their sustainability data, which will offer Little Rocket a big customer base.
This environmental sustainability rating offers a first step into a quantification of environmental sustainability on the basis of selected indicators from scientific literature.
To reach this goal and prevent creating “just another” sustainability index, a thorough literature review was conducted to prevent subjective bias in choosing indicators for the calculation of the sustainability index. This way only indicators were included that play a significant role in literature in measuring sustainability in the chosen sector. Additionally, indicators were chosen, based on the requirements, provided by governments to achieve the sustainable development goals. Based on the found indicators from the literature review the composite index was built using mathematical aggregation, weighting and normalization methods. This approach was discussed in multiple interviews with experts in the field of sustainability and mathematics, to confirm and validate the process and minimize bias.

The overall structure of this thesis takes the form of seven chapters including this introduction. The design science methodology, as well as the research procedure used for this research will be described in the second chapter. Within the third chapter, the theoretical background and the literature review will be provided which were used to build the basis for the sustainability index. In the fourth chapter of this thesis the design of the environmental sustainability index, together with the individual steps will be provided. The fifth chapter will offer a short description of how the necessary data for this index will be acquired, as well as which quality standards this data has to fulfill. Additionally, the fifth chapter will present the applicability of the proposed index which will be illustrated based on a use case of a company from the industrial sector of the Netherlands. The sixth chapter of this thesis will present the discussion and will evaluate the proposed solution, compare it to existing products, as well as uncover its limitations. The concluding seventh chapter will provide an answer to the proposed research question as well as give an outlook for future research.

2. Methodology

This chapter provides a detailed overview of the research procedure used to develop an environmental sustainability index. First, the used Design Science Research Methodology (DSRM) is explained and why it was chosen for this study. Second, the individual steps of the research procedure are presented and how they align with the DSRM.

2.1 Design Science Research

This study attempts to develop an index on which European companies can be rated regarding their environmental sustainability. Since this rating method was developed for a Little Rocket, who are inherent in the Netherlands, the use-case was utilized on companies from the industrial sector from the Netherlands. Companies from the industrial sector were chosen, since they have a massive impact on the environment, as explained in chapter 1. For the use-case, some of the largest Dutch industrial companies were chosen. The data for these companies was taken from the Euronext stock exchange.
This research was conducted according to the Design Science Research Methodology to develop a quantifiable environmental sustainability index.

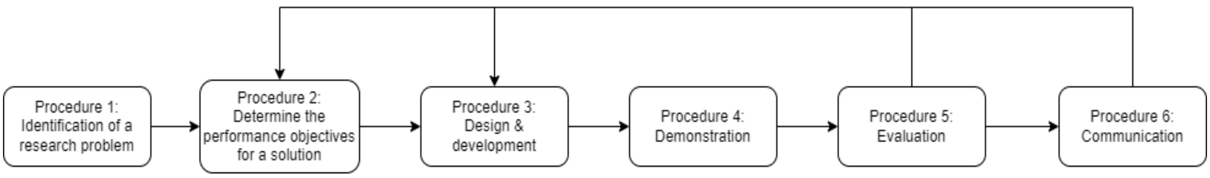

Figure 1: The Design Science Research Methodology

The design science research methodology (figure 1) was chosen here, since the development of an index regarding the environmental sustainability, describes the creation of an artifact which attempts to serve a human purpose and fulfills a human need (Hevner et al., 2004 & Peffers et al. 2007). Peffers et al. (2007) describe design science as “the involvement of rigorous processes to design artifacts to solve observed problems, to make research contributions, to evaluate the design, and to communicate the results to appropriate audiences”. The most important information that can be taken from this definition is that the research must produce an “artifact to address a problem” (Hevner et al., 2004 & Peffers et al. 2007). In the frame of this research this will be the environmental index for companies, trying to solve the problem of quantifying environmental sustainability for companies, so that stakeholders can compare companies over time and against each other.
To derive an environmental index, as a research artifact, the six step DSR approach shown in figure 1 was followed, from defining the research problem, to communication of results towards stakeholders. According to the first step of the DSR process, the research problem, as well as the proposed solution were defined in chapter 1. The research problem, which is that there is no unified quantification for environmental sustainability, can be solved by creating a quantification of multiple indicators from scientific literature, which, added together, describe the overall environmental sustainability of companies. The development of this solution would on the one hand add to the scientific advances within the field of measuring environmental sustainability, and on the other hand create a business service for a data driven company as Little Rocket. This step shares similarities with the first two

guidelines proposed by Hevner et al., which says that the design science research requires the creation of innovative, purposeful artifacts for a specific problem domain (Hevner et al., 2004).
Within the second step of the DSR process, the performance objectives for a solution were defined. Here the current state of knowledge is presented and what is possible and feasible with the proposed solution, which is described in more detail within chapter 1. The current state of knowledge was researched by conducting a literature review in sub-chapter 3.6 on environmental indicators within the industrial sector. In this process step the desired solution was defined and how the new artifact is expected to support solutions to problems not addressed yet (Peffers et al. 2007).
The next step of the research process was to design and develop the research artifact, for which a variety of literature and mathematical models served as a knowledge base. This is also in line with the DSR procedure provided by Peffer et al. (2007), as well as with guideline 5 defined by Hevner et al. (2004). To design the artifact a normalization method was used to combine all indicators on a single scale, which makes them comparable against each other. In addition to that, these indicators were aggregated to clusters, and afterwards to a single composite index. This process will be described in more detail in the sub-chapters 4.1 to 4.7.
Within the fourth step of the DSR process the developed artifact was demonstrated on a use case, to verify that it tries to solve instances of the research problem. To acquire data for the demonstration, annual- and sustainability reports of companies were manually scanned, analyzed and filled into the framework to receive results. After the manual data collection, the developed formulas have been used to calculate the values used for the final index.
The fifth step of the DSR process deals with the evaluation of the results of the previous steps. To evaluate the results multiple techniques were used to reduce subjective bias as much as possible. One chosen technique for the evaluation of the indicators, the normalization, and the aggregation techniques, was the technique of conducting expert interviews. Here the individual steps of the research procedure were presented and discussed. Within these interviews positive feedback was acquired regarding the selection of indicators, as well as the procedure to calculate an environmental composite index. Next to positive feedback also multiple points of discussion were addressed. Regarding critical points more research was conducted and the results were in a later interaction verified. For the evaluation of the final result of the artifact, the results were compared to existing frameworks, to see if similarities or major differences exist. The comparison was based on comparing the final values of the here developed index to existing results of frameworks.
Sub-chapter 3.2 communicates the problem and its importance, and sub-chapter 6.1 the utility and novelty of the solution, as well as its effectiveness to the research field, which is, next to Peffers' procedure, also in line with guideline 7 by Hevner et al. (2004). Furthermore is a detailed description provided on how the artifact was constructed and evaluated to offer more transparency. This entire process has similarities to guideline 6, by Hevner et al. (2004), and was conducted in an iterative manner. By receiving feedback on a regular basis, this feedback and the results from the evaluation have been taken to further develop the basis of the artifact and the performance objectives, in addition to the artifact itself.

2.2 Research Procedure

Figure 2 shows an overview of the procedure followed in this research to create an environmental composite index, which is aligned with methodologies for creating composite indexes (Krajnc & Glavič, 2005). As already mentioned, the indicators were selected according to a literature review and the analysis of existing frameworks and guidelines. The reason for this was to design a basis for an unified index, that is trustworthy and offers comparability, which was identified as the main problem within the field of environmental sustainability of companies.

Selecting the indicators was done within an iterative approach, where the findings of both the analysis and the review were compared after each cycle. These indicators were also analyzed based on requirements that have been set for the final environmental index in sub-chapter 4.1. Additionally, two more iterations were included, where first only indicators regarding the industrial sector were analyzed and later also from other sectors to find similarities. These steps can be seen as the second step by Peffers in sub-chapter 2.1. To validate if the found indicators are viable to build an environmental index on, semi-structured expert interviews were conducted. If the outcome of the validation was positive, relating to fulfilling the requirements in sub-chapter 4.1, the next step in the procedure was followed. If the requirements were not fully fulfilled, more research was conducted. Next to the expert interviews, the annual reports of the companies were analyzed. This was done, to see if a valid use-case (chapter 5), with enough data, can be performed on the defined indicators.

After viable indicators were identified, they were classified into clusters to create a better overview of which indicators belong together. This is also in line with Peffers' third procedure of designing and developing an artifact. Additional reasons for the clustering of indicators were transparency and to better present stakeholders, of different kinds, in which cluster they perform good or bad. To make changes easier within the environmental index was an additional reason for the clustering of the indicators.

Following up the clustering of the indicators, a classification of indicators depending on if they have a positive or negative influence on the rating was performed. This is important since the increase or decrease of the value of an indicator may differ in the resulting influence on the environmental performance of a company. For example, would an increase in CO2 emissions cause a negative influence on environmental performance, whereas an increase in renewable energy usage has a positive influence on environmental performance of a company.

After the indicators have been identified, clustered, and characterized according to their influence, formulas have been set up to normalize the indicators to make them comparable. For normalizing the indicators multiple iterations were conducted to test different normalization methods. To test different normalization methods, collaborations and discussions with other researchers from the field of environmental sustainability were conducted. To test normalization methods, email-discussions with researchers took place, to understand why they used certain variables and techniques within their research. After multiple iterations the min-max-normalization was chosen, on which will be more elaborated in sub-chapter 4.5.

The normalized indicators have then received weights. To analyze which weighting method entails the least amount of subjectivity, the individual methods were thoroughly analyzed. Additionally, expert interviews validated that the findings contribute to dealing with current problems in environmental indexes. After the indicators received weights, they were aggregated to cluster indexes and later these clusters were combined into a total environmental index. After the environmental index was designed and developed, chapter 5 offers a demonstration of the artifact. This is also in line with procedure 4 of Peffers' DSR methodology. After each of these steps within the research procedure, validation phases were included, which can be seen in figure 2. Here expert interviews were conducted to see if the index consists of the right building blocks and fulfills the set requirements, presented in sub-chapter 4.1. The interviews had the build-up of semi-structured interviews. The reason semi-structured interviews were chosen was that each expert had a different specialization and therefore profound knowledge within a certain field. Each expert was asked a core set of questions relating to the current problems, the findings of this study, and how these findings might help to solve the current problems. Next to the core set of questions, each expert was asked additional questions, based on their specialization within the field. Most of the experts were interviewed multiple times, to validate the procedure and discuss pain-points. This procedure with the expert interviews is in line with the DSR methodology presented in sub-chapter 2.1. Here the expert interviews represent the procedure 6 of communication.

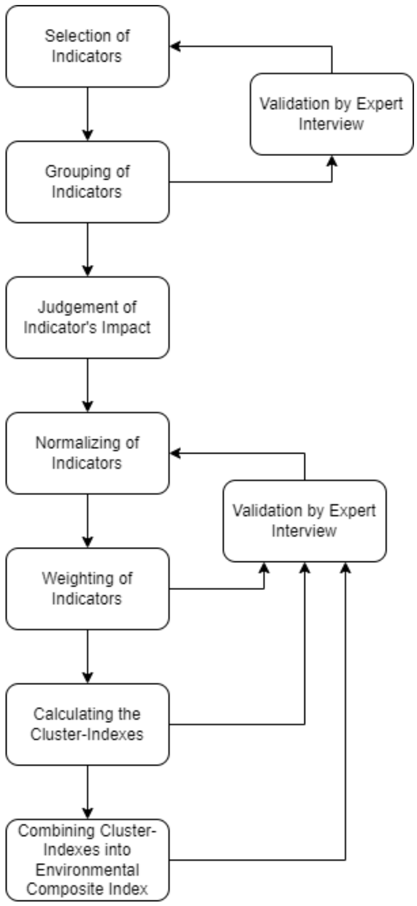

Figure 2: The Research Procedure

Following the build up of the index, a use-case was conducted to present, if the developed index, helps towards solving the identified problems. The use-case and the data collection will be closer described in chapter 5.
After the iterative development of this research has been presented, the historical development of the term "sustainability" will follow up. This historical part will demonstrate a short introduction into the comprehensive findings from literature.

3. Literature Review

This chapter presents the theoretical background of the term sustainability, as well as introduces the method of quantifying environmental sustainability through an index. First a historical background will introduce the development of the term sustainability. Second, a detailed view is presented, why environmental sustainability is becoming important for companies. Following up, it is described how data analytics technologies can help towards becoming more sustainable. This chapter concludes with a literature review and the selection of the most important indicators from the literature.

3.1 Historical Background

The term sustainability has its origin from the forestry sector in the 18th century. The term grew out of the need to address a timber shortage crisis in Europe. To manage this crisis, Carlowitz (1713) developed the idea that an ever growing scarcity can be avoided by a “careful management of forestry resources” (Somogyi, 2016). Later this idea evolved into a standard in forestry. With time more and more of such standards came in different sectors to life to address scarcities and mismanagement.
The publication of Our Common Future in 1987 marked a turning point in thinking on environment, development, and governance. The UN-sponsored World Commission on Environment and Development (WCED), issued a call to recalibrate institutional mechanisms at global, national and local levels to promote economic development that would guarantee “the security, wellbeing, and very survival of the planet” (Brundtland, 1987). The call for sustainable development was a redirection of the enlightenment project, a pragmatic response to the problems of our time. The Brundtland report gave further direction to comprehensive global solutions, by defining sustainable development as development which “meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (Moldan et al., 2012). At the 1992 United Nations Earth Summit in Rio de Janeiro, sustainable development emerged as one of the most urgent subjects for international policy (Chichilnisky, 1997). Since then a variety of additional definitions came up to describe sustainable development as, for example “development in which there is an improvement in the quality of life without necessarily causing an increase in the quantity of resources consumed” (Loucks, 1997).

As can be seen by the development of this field, did the term sustainability first only cover the pillar of environmental sustainability. With the later introduction of the Agenda 21 and several newer definitions developed during sustainability summits the field added with “social” and “economic” two more pillars. The evolution of the term “sustainability” can be seen in table 1, where multiple newer definitions were included.

Author	Definition
Salvado et al., 2015	“Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present but also for future generations.”

Harrington, 2016	“Sustainability is the capacity to maintain or improve the state and availability of desirable materials or conditions over the long term.”
Meadowcroft, 2022	“In general, sustainability is understood as a form of intergenerational ethics in which the environmental and economic actions taken by present persons do not diminish the opportunities of future persons to enjoy similar levels of wealth, utility, or welfare.”

Table 1: Definitions of sustainability

Using these definitions as a basis, the United Nations (UN), along with the European Union (EU) introduced sustainable development goals. On 25 September 2015 the Agenda 2030, including its 17 sustainable development goals (SDGs) and 169 targets, was introduced by the Heads of State and Government at a special UN summit (European Commission, 2015) and replaced the millennium development goals that expired that year (Hsu et al., 2013). The Agenda defines a commitment to eradicate poverty and achieve sustainable development until 2030, as well as tackles issues such as natural resource management, sustainable consumption and production (European Commission, 2015). Therefore, encourages all member states to develop as soon as possible ambitious national responses to the overall implementation (United Nations, 2015). Next to the UN, the EU also proposed, with the “Green Deal”, environmental goals for 2030 and 2050, to restore Europe’s nature. Measures to make Europe more environmentally friendly have not only an impact on nations and companies within Europe, but also have a global effect (European Commission, 2022). This is due to the fact that European countries import many resources and products from other countries, which, over time, will not be marketed if they contain residues of prohibited substances or do not conform with European sustainability standards (European Commission, 2022).

The “Green Deal” tackles multiple of Europe’s environmental problems and concerns by proposing a strict plan and goals. With the “Green Deal”, the EU wants to reduce the risk for the environment and avoid an ecosystem collapse, preventing worse impacts of climate change and biodiversity loss. The EU underlines that a healthy and resilient ecosystem is the backbone of the well-being and the prosperity of Europe, providing food, clean water, carbon sinks and protection against natural disasters caused by climate change. Therefore the EU set goals to produce no net-emissions of green-house-gasses by 2050 by industries and to decouple economic growth from resource use. This, while being in line with the UN agreement of 2015 to keep global temperature increase below 2 degrees of celsius (European Commission, 2022). These goals count for every company within the individual countries. Companies account for a large amount of emissions, effluents and waste that each nation produces, which needs to be tackled.

3.2 Sustainability in Companies

Companies have a significant influence on the environmental sustainability of the planet and can, through their guidance, change their impact on the environment. As mentioned in chapter 1, currently 40% of listed companies on the European stock exchanges produce approximately 80% of greenhouse gas emissions in Europe and have therefore a significant impact on the wellbeing of Europe's environment (European Commission, 2022).

Decisions and environmental strategies of companies have not only global, but also national and local environmental influence and may have different impacts on different levels (Moldan et al., 2012). On the global level, the SDGs, implemented by the UN, defined goals which serve the environmental sustainability of this planet. These goals, intended to raise the sustainability of nations and companies, show lower effectiveness than expected, because of their voluntary nature and vague goals, which makes them easy to ignore for companies (Diouf & Boiral, 2017 & Hsu et al., 2013). Additionally, measuring environmental sustainability entails a lot of work and major costs (Boggia et al., 2018), which raises the rejection of companies towards such measurements and voluntary goals.

In addition to the subjective nature of these goals and the extra costs measuring and reporting the progress towards them, multiple other problems come up when measuring environmental sustainability, including:

- There exists no clear definition of which key performance indicators (KPIs) to include (Krajnc & Glavič, 2005). This allows companies to report in different ways, which is not beneficial for making comparisons.
- As a consequence, "Greenwashing" has also been posing a big problem in the field of companies reporting their environmental sustainability. Companies often use different strategies to manipulate users' opinions or guide them towards a more favorable picture creation of the company (Diouf & Boiral, 2017).
- Many companies do not report their environmental sustainability data unless they are asked to, or it becomes mandatory for them by law.

These and multiple other problems underlie the open potential in measuring companies environmental sustainability, as these play a major role in influencing the environmental sustainability of a nation. The use of this potential is dependent on the perception of companies regarding the importance of their measurements and acceptance of these goals (Rusche et al., 2021). With time more and more companies become aware of the increasing importance of environmental sustainability. An accumulating amount of factors influence the awareness of companies of the importance of increasing sustainability. Additionally to norms and governmental regulations, an increase in competitive pressure is visible (Pangarso et al., 2022). More and more companies are joining the sustainability movement, which gives them an advantage over competitors, which have not acknowledged this movement yet. This movement is supported by the so-called "green customer", whose characteristic is a demand for sustainable products and services, due to an increased awareness of the irreversible phenomena caused by the current pattern of consumption and production (Boggia et al., 2018).

Currently, sustainability measures are often the result of the demand for transparency by customers, as well as pressure by the legislative, which mainly serve the goal of having a good reputation and image (Rusche et al., 2021). But because of the rising importance of sustainable products and services, companies are taking measures to plan for the long run and to grab advantage of the offered potentials. Next to the rising importance of sustainable services and products, technological capabilities allow to measure the in- and outputs of

companies to produce these services and products. These measures lead to an increase in attention of investors in more sustainable companies.
An increasing number of investors seek to invest in more socially and environmentally responsible companies (Keller, 2015). As this form is getting increasingly popular, companies are increasingly required to disclose environmental information (Cardoni et al., 2019). Companies want to motivate their investors to undertake more investments into the company and therefore upgrade their reporting standards to reduce investment risks, satisfying investors' risk-averse preferences. This is due to the fact that negative environmental information jeopardizes a company's reputation, triggers investors' concerns and exits, and severely damages a company's ability to raise capital (Chen & Xie, 2022).
With the increasing amount of attention brought towards the sustainability of companies, more and more rating agencies popped up to create rankings for companies based on the TBL features (Keller, 2015).
This increased number of rating schemes being introduced to the market makes it difficult for companies and investors to choose which is the most suitable one (Keller, 2015). From a practitioners point of view, one of the main factors that limits the use of sustainability information is the lack of comparability across companies. This is also supported by academic studies, claiming that the largest challenge for investors in integrating sustainability information in their investment process is the lack of cross-company comparability (Cardoni et al., 2019).
A study by the Tellus Institute demonstrated and underlied that comparability is the single most important characteristic of environmental performance indicators (Veleva & Ellenbecker, 2001). Therefore it is outerly important to have comparable indicators that count for everybody within an industry. This is also acknowledged by the Global Reporting Initiative (GRI), which states that reported information should be presented in a manner that enables stakeholders to analyze changes in the organization over time, and could support analysis relative to other organizations (Diouf & Boiral, 2017). This is also discussed by Olsthoorn et al. (2001), who criticize the current state of reporting, since the majority of environmental information is only being used to compare organizations over time, with little comparability offered between organizations. These findings underlie the fact that sustainability reportings should be comparable, so that companies' performances can be compared against benchmarks or against other companies in the industry.
The increase in popularity of sustainability reports poses a problem for this industry. With no defined standard, companies report their environmental data in different ways, which resulted in an increase in different reporting frameworks and rating schemes.
Companies are either publishing their own sustainability reports, use one of the many available standards and frameworks, or are being rated by one of the many rating schemes. The outcome of such a situation may be a "market of lemons", where stakeholders cannot identify sustainability-oriented companies, because of a lack of comparability of information or trust in the offered information (Windolph, 2011). This lack of trust in disclosed information is due to the fact that companies try to win a favorable impression from customers and investors and therefore might only report information that shows them in a good light (Diouf & Boiral, 2017). Additionally, the number of rating schemes poses a problem to stakeholders. Different rating schemes use different information, weights, and methods to calculate environmental performance scores without any transparency (Keller, 2015). This makes it difficult for customers and investors to understand what the individual sustainability scores mean and what has been measured.

These problems have a lot of negative influence on the important topic of environmental sustainability. One way to address this problem can be through the use of technologies, such as big data analytics, artificial intelligence, and the internet of things, which will be explained in the upcoming sub-chapter.

3.3 Data analytics technologies in the field of Environmental Sustainability

Technologies such as Big Data Analytics, artificial intelligence (AI), and the Internet of Things (IoT) are transforming the ways companies see themselves, as they offer new possibilities in how companies measure, analyze, and control the impact of their actions. This also counts for environmental sustainability related issues, where new technologies offer new ways in how companies measure their sustainability related issues (Feroz et al., 2021). Companies are more and more relying on artificial intelligence, the Internet of Things, and Big Data Analytics to better understand their own business and keep up with the information demand of customers. These new technologies also offer new ways to carry out sustainable business practices that involve reduced carbon emission and a minimized impact on the environment (Feroz et al., 2021). Big Data Analytics applications, for example, are increasingly changing how the impact on the environment is measured and mapped. In addition, companies can also identify patterns and trends that may not have been immediately apparent. This is also supported by researchers, saying that Big Data has massive potential on the future impact of sustainable development and can support organizational goals towards improving environmental sustainability (Dubey et al., 2019).

The power of Big Data is usually related to predictive analytics that use statistical knowledge to forecast future events based on the assumptions that what has occurred in the past may have influence on future events (Dubey et al., 2019). Therefore, data driven companies are offered opportunities to assess their current state of handling environmental sustainability and how this current state may influence future developments. By gaining deep insights, data driven companies are offered a competitive advantage, since they can better measure and change their impact on the environment (Zhu et al., 2022). Furthermore, a big variety of open data sources, provided by different stakeholders, can be used to create further comparability to thresholds and sector averages. The combination of different data sources allows analysts to get deeper insights into hot topics, such as sustainability.

This is confirmed by Feroz et al. (2021), saying that the application of Big Data in analyzing millions of records is an unprecedented development that has a positive signal in the environmental sustainability area. He further states that such developments hold huge potential for governments, NGOs, and companies. This potential counts for business creation, policy implementation, and improving social life. Numerous studies support this argument, by reinforcing that Big Data Analytics can translate data into valuable insights that may aid decision making (Zhu et al., 2022 & Raut et al., 2019).

Next to big data analytics, IoT plays an increasingly important role in measuring environmental impact. IoT can be used to collect real-time data about environmental performance, enabling companies to monitor their operations in real-time and identify areas for improvement (Salam, 2019).

AI offers to be a perfect partner for all these measurements and collected data. AI can be used to analyze and interpret the data related to environmental performance, helping companies and their decision makers to identify patterns and trends that would be difficult for humans to detect (Nishant et al., 2020). By using AI to analyze data, companies can identify where they can improve their performance and make more informed decisions about how to reduce their environmental impact.
These technologies of Big Data Analytics, AI, and IoT enable new ways to collect large quantities of measurements and data points. Taking all possible indicators, related to sustainability, into consideration can be very time consuming. Additionally, measuring every possible indicator can be very deceptive to make decisions on. One way to help make more informed decisions can be an index, consisting of an aggregation of selected indicators. Indexes might also create more clarity by showing the environmental impact of a company within a single index, as described in the following sub-chapter.

3.4 Environmental Performance Index

A variety of different approaches exist in literature to measure sustainability on different levels, such as nations, cities, and companies. The World Business Council of Sustainable Development and the Global Reporting Initiative were the key drivers for adoption of sustainability management in industries (Singh et al., 2012). Next to these two, there are a number of sustainability assessment methodologies that exist in practice for evaluating the performance of companies. One common approach of measuring the environmental pillar is the concept of composite environmental performance indicators. This approach is based on the mathematical aggregation of an amount of environmental indicators (Zhou et al., 2012).
Composite indexes help decision makers by drawing attention to particular issues, identifying benchmark performance and trends, and setting policy priorities. Providing a bigger picture, composite indexes are often easy to interpret by stakeholders and the media. This makes them an eye-catcher and therefore, an attractive instrument for public communication (Rogge, 2012 & Li et al., 2012). Composite indexes have the advantage of flexibility. Indexes can be extended or shortened by adding or cutting of indicators depending on the need of the index. This advantage remains controversial, because it is frequently argued that composite indexes are too subjective, due to the assumptions made which indicators to include (Zhou et al., 2012 & Harik et al., 2015). This can result in composite indexes to deliver misleading policy messages if they are poorly constructed or misinterpreted (Li et al., 2012 & Spangenberg & Bonniot, 1997).
To counter these disadvantages multiple frameworks developed guidelines on what indexes should include in measuring sustainability of companies.

3.5 Environmental (Key) Performance Indicators

In order to address issues related to sustainability, understanding the relevant indicators is required (Stanitsas et al., 2021). Key performance indicators (KPIs) are the main building blocks of and essential for the measurement of environmental composite indexes (Rusche et al., 2021) and have the ultimate aim of helping to address the key sustainability concerns (Krajnc & Glavič, 2005). The selection of KPIs for the calculation of composite indexes has received a lot of criticism though, considering the selection of indicators has a very subjective nature due to differences in perception of stakeholders (Rusche et al., 2021). The topic of KPI selection has also received a lot of negative attention, since companies choose indicators for their rating that show them in a better light than they actually are.

This problem can be partially addressed by focusing on world-wide accepted methodologies and guidelines. One of these guidelines represents the Global Reporting Initiative (GRI). GRI represents practices for reporting publicly economic, environmental, and social impacts and is built from a modular system of interconnected standards (GRI, 2022). Li et al. (2012) state that GRI is set as a good source of reference for the selection of indicators, which limits the variety of possible indicators to report. This would support the comparability of companies reporting sustainability, since these would be based on the same set of indicators (Diouf & Boiral, 2017).

Next to the GRI standards, are the 17 goals, as well as the 169 targets of the 2015 introduced SDGs of big relevance. This is due to the fact that areas have been defined, where measurable indicators can be distinguished (Rusche et al., 2021). These goals give stakeholders concrete identifiable targets they need to reach. An additional advantage is that these SDGs are accepted by all members of the UN, which gives them world-wide approval. A major disadvantage of the SDGs is that they do not define concrete, clear and accepted KPIs that have to be measured to reach their goals.

Additionally to the standards, promoted by the GRI, and the goals of the SDGs, the EU created a common classification system for sustainable economic activities, the so called “EU Taxonomy”. The EU Taxonomy is a classification system, establishing a list of environmentally sustainable economic activities and indicators for different sectors. This taxonomy plays an important role, helping the EU scale up sustainable investment and implement the European Green Deal. The EU Taxonomy provides companies, investors and environmental policymakers with appropriate definitions for economic activities that can be considered environmentally sustainable (European Commission, 2022).

Having different standards and classifications being important for the same stakeholder, poses problems for deciding which standards or goals to follow. The EU Taxonomy, helping to implement the European Green Deal, which was based on the Paris Agreement and the SDGs, does not share all of the goals across with the different standards (Koundouri et al., 2021). According to different computational testing methods by researchers, differences in some of the proposed sustainability goals were uncovered (Koundouri, 2022).

By focusing on the mentioned standards and classification systems as well as a thorough literature review, KPIs, which were included in all of them, were selected to measure the environmental impact of companies within the industrial sector of the Netherlands in the later presented use case.

3.6 The Environmental Pillar

As mentioned in earlier chapters a concept centric literature review was conducted to find the most influential KPIs influencing the environmental pillar of the TBL (see figure 3). An additional reason was to see if researchers deeme the same KPIs important as common reporting frameworks, such as the GRI standard or the SDGs. To find literature around the concept of environmental sustainability measures, two databases, with multiple search terms were utilized. The two databases used for this literature review were Google Scholar and Scopus. These two databases were chosen, since they individually offer a multidisciplinary choice of scientific and scholarly literature and together cover a wide range of literature regarding specific topics in the IS field.

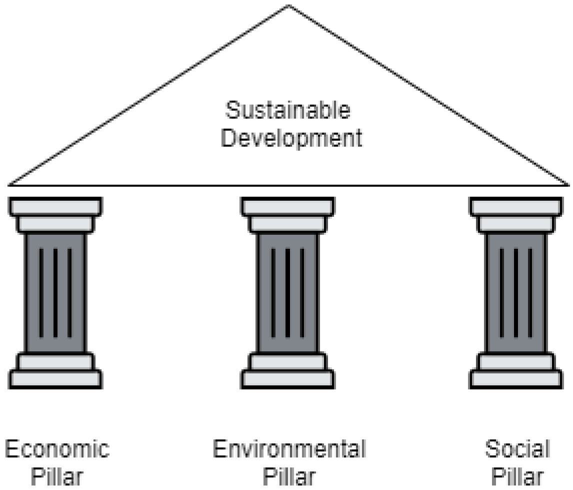

Figure 3: The Triple Bottom Line (TBL)

During this literature review a total of 96 articles, books, journals, and papers were analyzed, based on the search terms listed in Appendix C. To select literature relevant for this research, abstracts, introductions, and discussions were analyzed on the topic of sustainable development. The findings of this literature review were collected and aggregated into a concept matrix, to create a better visibility of the amount of found indicators, including the number of how often an individual indicator was named. Additionally was this literature review not restricted to just the industrial sector, to see what indicators are generally reported in all sectors. This had the reason to find out which indicators have to be reported due to their high relevance and environmental impact, as well as simple measurability. As a result of this literature review a total of 38 indicators were found in the 19 articles, books, journals, and papers that discussed frameworks and indicators regarding measuring environmental sustainability.

To derive a composite index, describing the environmental sustainability of a company, the following systematic approach has been followed:

1. Selection of indicators (sub-chapter 4.2).
2. Normalizing the indicators (sub-chapter 4.5).
3. Assigning weights to the indicators (sub-chapter 4.6).
4. Aggregation of the indicators to cluster indexes and an overall environmental sustainability index (sub-chapter 4.7).

In the first place the shortened resulting concept matrix from the literature review can be seen in table 2 (the full framework from the literature review can be found in Appendix B). Noticeable is that indicators regarding energy, water, air, and waste are some of the most discussed indicators.
These findings are in line with the goals set by the SDGs, in addition to the standards defined by the GRI. Both include benchmarks and measures to evaluate the individual company score against.

\	Literature		\	Literature	
Indicators	Literature in total	Literature mentioning this indicator	Indicators	Literature in total	Literature mentioning this indicator
Energy usage	19	13	Natural resource use	19	9
Energy efficiency		8	Material consumption		10
Renewable energy usage		9	Hazardous materials used		1
Energy from non-renewable source		4	Recycling of own materials		5
Air Pollution (Ghg)		17	Use of recyclable materials		7
Emissions of acid gases		1	Use of packaging materials		1
Ozone depletion		1	Use of recycled packaging materials		3
Pollution prevention		1	Noise pollution		2
Water usage		13	Light pollution		2
Fresh water usage		1	Heat pollution		1
Water pollution		9	Overshadowing		1
Water recycled		5	Transport and cycling materials		1
Non-hazardous waste produced		11	Hazardous events		2
Waste recycled		4	Environmental policy		6
Hazardous waste produced		8	Lifecycle of products		2
Reuse of hazardous waste		1	Biodiversity		5
Fossil fuel usage		2	Land use		3
Assessment framework		3	Environmental budget		1
Regulatory violations		4	Product-end-of-life		3

Table 2: All found indicators from the literature review

This limited amount of found indicators will be used in the further procedure of building a composite environmental sustainability index. This has the reason because it is extremely difficult to have a set of sustainability indicators, applicable to any company or organization within a sector, due to different business activities (Krajnc & Glavič, 2005 & Veleva & Ellenbecker, 2001). Additionally do Veleva & Ellenbecker (2001) point out that it is better to measure the right things approximately than the wrong ones with great accuracy and precision. They further say that while some issues are common for all companies, such as energy and water usage, the differences in facilities are enormous and a standardized set of sustainability indicators may miss the key impacts. Therefore this framework limited itself to only measure these four clusters, since a large number of companies have these in common.

The found indicators regarding energy, water, air, and waste have been defined as cluster indicators in this research, with multiple sub-indicators included in and describing these cluster indicators. These sub-indicators have also been taken from the literature review, as well as the GRI standard.

The amount of sub-indicators describing one cluster indicator has been tried to be limited to be as minimal, but explanatory as possible. This has the reason to reduce the complexity of the final index. Therefore the three most named indicators were included for each cluster indicator.

The sub-indicators, discovered from the literature review, for the water cluster are total water usage, water pollution/discharge, and water recycled. The sub-indicators chosen for the energy cluster are total energy usage, renewable energy usage, and generation of own renewable energy. The third cluster, being the waste cluster, has the sub-indicators of total non-hazardous waste generation, total hazardous waste generation, and waste recycled.

Last but not least describes the air/emissions cluster the total CO_2 emissions (scope 1-3), the total NO_x emissions, as well as the total SO_x emissions.

Subsequent to the selection of indicators for the index, all the indicators need to be normalized. Environmental data is often displayed without known standardization or conversion factors, and with limited information as to what the data refers to or includes. This makes comparison between companies difficult. To increase transparency and credibility, environmental data should be normalized (Gautam & Singh, 2010), by transforming various scales of variables into one unique scale (Böhringer & Jochem, 2007). Data normalization is technically consistent with the methodological development of composite indexes (Sun et al., 2020). The transformation into a unique scale should be done, so that afterwards the data can be standardized and aggregated (Olsthoorn et al., 2001).

Aggregation transforms data into different forms and formats. In this study, measurement data of different indicators are combined into a single value. This can be done by multiplying or, as in this case, adding these normalized data points together. This allows better understanding or interpretation of the data by different groups or for different purposes (Olsthoorn et al., 2001). Data aggregation for an index is also demanded by policy makers. This allows for a quick overview of current environmental status (Böhringer & Jochem, 2007), as these summarize the measurements of multidimensional concepts (Sun et al., 2020; Olsthoorn et al., 2001 & Gautam & Singh, 2010).

The step of normalizing indicators receives a lot of attention in literature. This is due to the fact that the environmental index depends a lot on how the individual indicators are normalized. A variety of normalizing methods exist in literature, such as the “minimum-maximum principle” and the “distance to a reference principle”. Therefore it is difficult to compare indexes across sectors, because ratings of different sectors might be using other normalizing methods (Rusche et al., 2021).
Against this background, the aim of this work is to develop a sustainability index for the evaluation of companies that measure environmental sustainability at both the process and product level. This evaluation is directly derived from concrete sustainability goals and guidelines, and enables interpretation of the result by stakeholders as a stand-alone index as well as in comparison with other companies and products.

4. Designing the ESI

This chapter presents a detailed, transparent manner of how this environmental sustainability index (ESI) is developed. A step by step approach presents, on what basis of requirements the indicators were chosen and how these indicators were categorized, analyzed and later used for the ESI. A detailed description is provided why individual methods were chosen and how the final ESI is calculated. This detailed description of the design procedure lays the foundation for the discussion, why this proposed ESI solves current issues with environmental ratings.

4.1 Requirements Analysis

As already mentioned in the introduction, to create a meaningful ESI for companies, the first step is to check if the selected indicators taken from the literature review fulfill the set requirements (table 3), as well as address the problems stated in chapter 1. The requirements were defined for composite indexes in general and not specifically for digital indexes. Therefore leaving out requirements regarding digital features.
These requirements were divided into five dimensions and will be described in the following table 3 in more detail:

Requirements	
Meaningful	R1. The index of a company should by itself be meaningful and by itself be able to represent the environmental status of a company (Sun et al., 2020).
	R2. The index should, because of the dependencies to the law and literature, be applicable to other companies within the sector and by making viable adjustments also to companies in other sectors.
Simple	R3. The index should be easily comparable between rated companies, to create an overview which company received a better score regarding environmental sustainability.
	R4. The index should be based on significant measurable indicators (Krajnc & Glavič, 2005).
Measurable	R5. The index should be based on quantitative indicators, which are feasible to be objectively measured (Krajnc & Glavič, 2005).
Understandable	R6. The index should be understandable by and transparent for all stakeholders.

Complete	R7. The index should include all relevant indicators according to literature.

Table 3: Requirements

These requirements build the basis for the evaluation of the ESI and its cluster indexes in the discussion chapter 6.2.
Regarding these requirements the individual indicators were analyzed and selected to design the basis for the composite index.

4.2 Selection of Indicators

After the requirements for the selection of the indicators have been set up, individual indicators need to be checked if they fulfill the set requirements. One of the major characteristics of an environmental composite index should be that it is in line with the political and scientific requirements. One of these requirements is that environmental indicators should be meaningful and simple to be measured, which is supported by (Sun et al., 2020).
The four clusters chosen for this research fulfill these requirements, because all of them get addressed by international, as well as national goals and objectives. Corresponding to this, the clusters also fulfill the requirement set by the SDGs, by being globally relevant and applicable to a broad range of countries (Sachs et al., 2020). Additionally, all four clusters are addressed as major fields in which sustainability needs to be addressed and measured, supporting the meaningfulness of these clusters. The meaningfulness of these clusters and indicators is also addressed since they tackle relevant sustainability topics for the upcoming years (Sachs et al., 2020). In addition to this, these four clusters are simple to understand, and measurable in numerical terms. Because of the numerical measurability of these clusters, a comparison can be made between individual companies, which is of major importance according to literature, governments, and stakeholders of different kinds. The clusters, indicators, as well as the description for each cluster and the indicators within these clusters was chosen, so that stakeholders of any kind can understand what these indicators measure and represent. In terms of the completeness of the indicators, sacrifices had to be made to keep the index simple, transparent and understandable. The three most referenced indicators from the literature were identified and included for each cluster, as well as checked if they are relevant to political requirements.
Only indicators that are able to fulfill these requirements are included in the framework (table 4 and 5) and the later calculation of the ESI. This is also widely discussed in literature since the selection of indicators forms the basis of any composite index and has therefore a direct influence on the final rating (Böhringer & Jochem, 2007).
All the analyzed indicators, which fulfilled the requirements and fell into one of the four clusters, are displayed in the following framework (table 4 and 5).
In the frameworks of table 4 and 5 it can be seen that the indicator of “% of own sustainable energy production” (named “own energy production”) is the only indicator that was included without being named in scientific literature. This is due to the reason, that other factors relating to energy consumption in literature had high similarities to the indicator of “energy

usage” and “% renewable energy usage”. To overcome measuring the same numbers twice this indicator of own energy production was included. This finding was worked out, evaluated, and validated in multiple conducted expert interviews. Additionally, a large number of companies do already report their own produced energy. These were the reasons that this indicator was included in the framework, even if this indicator was not mentioned in scientific literature.

It is also notable that some not included indicators were mentioned more often than certain indicators that were included in this composite index. This is because the disregarded indicators are not part of the four clusters, this research focused on. Therefore these indicators were not included in the composite index. The clusters, which were chosen for the basis of the ESI, are more closely presented in the upcoming sub-chapter 4.3.

	Environmental Pillar											
	Indicators											
Literature	Total Energy Usage	Renewable Energy Usage	Own Energy Production	CO2 Emissions (Scope 1-3)	NOx Emissions	SOx Emissions	Total Waste Production	Recycled Waste	Total Hazardous Waste Production	Total Water Usage	Water Discharge/ Pollution	Water Recycled
Aouadi and Marsat, 2018				x	x	x						
Barburdeen et al., 2014	x	x		x			x		x	x	x	x
Bassen and Kovac, 2008		x		x	x	x	x					
Gani et al., 2021	x	x		x	x	x	x	x	x	x	x	x
Garbie, 2014		x		x				x	x		x	x
Gautam and Singh, 2010	x	x		x						x	x	x
Gebhardt and Kefer, 2019				x	x	x				x		
Helleno et al., 2017	x			x			x	x		x		
Jiang et al., 2019	x			x	x	x	x	x		x	x	
Krajnc and Glavic, 2005				x	x	x						
Labuschagne et al., 2005	x			x						x		
Li et al., 2012	x	x		x	x	x				x		
Poveda and Lipsett, 2011	x			x	x	x	x		x		x	
Semenova and Hassel, 2015	x			x	x	x	x		x	x		
Seuring et al., 2003	x			x			x			x	x	
Stanitsas et al., 2021		x								x	x	
Torres et al., 2018												
Veleva et al., 2001	x	x		x		x	x		x	x		
Wenninger et al., 2021	x	x		x	x	x	x		x	x		
Total	12	9	0	17	10	11	10	4	7	13	8	4

Table 4: Indicators chosen from literature for the index

	Environmental Pillar											
	Indicators											
Frameworks	Total Energy Usage	Renewable Energy Usage	Own Energy Production	CO2 Emissions (Scope 1-3)	NOx Emissions	SOx Emissions	Total Waste Production	Recycled Waste	Total Hazardous Waste Production	Total Water Usage	Water Discharge/ Pollution	Water Recycled
LCSP	x	x		x		x	x		x	x	x	
WICI		x		x	x	x	x		x			
CDP	x	x	x	x	x	x	x		x	x		
MSCI	x	x		x	x	x	x		x	x	x	
GRI	x			x	x	x	x	x	x	x	x	
CSRD		x	x	x	x	x		x	x	x	x	x
EU - Taxonomy	x	x	x	x	x	x	x	x		x		x
SDGs		x		x	x	x	x	x	x	x	x	x
Total	5	7	3	8	7	8	8	4	7	7	5	3

Table 5: Indicators taken from existing agencies, laws, frameworks, and rating

4.3 Categorization of Indicators

For the next step to create the ESI, the found indicators, extracted from the literature review, have been categorized into “categorical indicators”, or “clusters” to create a better overview of which indicators belong to the same field of environmental impact (Badurdeen et al., 2014 & Zhou et al., 2012). This has the reason that adjustments to individual indicators or cluster indexes can more easily be done, than to make changes to an entire formula. Additionally, do individual cluster indexes make it possible to visualize the impacts and details of these individual clusters. Stakeholders, of different kinds, are able to see which clusters have a greater positive or negative influence on the final composite index and can therefore make adjustments, based on a reduced number of decision-making criteria, to positively influence the final rating (Krajnc & Glavič, 2005).
The developed “categorical indicators” or “clusters” can be seen in figure 4. The naming scheme of the individual cluster was oriented alongside the naming scheme of the GRI topics.

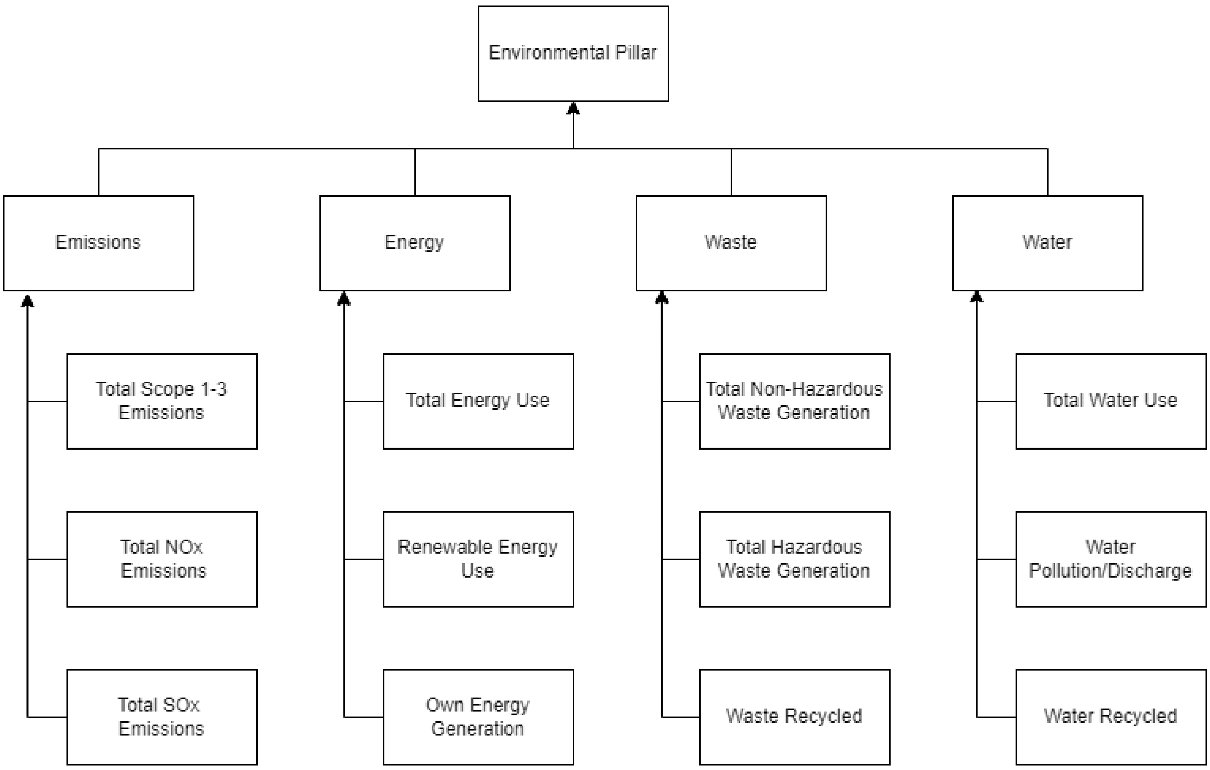

Figure 4: The Environmental Pillar with the chosen four clusters and their indicators

Figure 4 shows a representation of the environmental pillar and the four clusters from this research. It can be seen that each cluster includes three indicators, which have been presented in sub-chapter 3.6. The arrows show the way the indicators have to be aggregated to calculate the cluster rating and later the total environmental rating.

4.4 Impact of the Indicators

After the KPIs have been categorized according to their relevant clusters, each KPI was analyzed by experimenting with raising or lowering its total values. This has the main reason to communicate what influence these indicators will have on the final composite index (Gautam & Singh, 2010 & Krajnc & Glavič, 2005). By experimenting with the values of the indicators, it was possible to see if higher values of indicators have a positive or negative impact on the final rating.

KPIs can either have a positive or negative influence on the final value of the composite index. On the one hand for example, an increase in CO2 emissions would have a negative influence on the environment and therefore has to be rated negatively in this context. On the other hand, stands for example the percentage of recycled/reused resources for production. Here, higher values for this KPI would have a positive influence on the environment and therefore have to be rated positively.

To create a better overview of which KPI has a positive, and which has a negative influence, a table is presented hereafter (table 6).

This representation was chosen, since it offers a quick and simple overview of how many indicators have a positive impact on the final rating in comparison to the indicators with a negative impact. Therefore it can be observed that there is a far bigger number of indicators with a negative impact on the final rating than indicators with a positive impact.

Influence	Indicator
- (negative)	Total CO2 Emissions (Scope 1-3)
	Total NOx Emissions
	Total SOx Emissions
	Total Energy Usage
	Total Non-Hazardous Waste Generation
	Total Hazardous Waste Generation
	Total Water Usage
	Water Pollution/Discharge
+ (positive)	Renewable Energy Usage
	Own Energy Generation
	Waste Recycled
	Water Recycled

Table 6: Indicator Influence

It was deliberately chosen to include indicators with a positive impact, as well as indicators with a negative impact, even though the rating would be simpler if only indicators with the same sort of impact would be included. It was also decided against using inverted variables for the indicators. This had the reason that companies currently report their environmental data in a way that would make inverting the variables more complex, which would not be in favor of the set requirements. Companies mainly report their environmental data in total waste, water or emissions produced and not prevented. Therefore it was chosen to include both types of indicators.

4.5 Normalization

The next step following the selection and classification of the indicators is the normalization. The main problem with aggregating indicators into a composite index is the fact that indicators may be expressed in different units (Krajnc & Glavič, 2005). Therefore normalization needs to be applied for integrating selected indicators into a composite index (Zhou et al., 2012). Different indicators might get measured in different ways, have different value scales and different measurement systems. To combine the indicators all together into one index and to make them comparable, mathematical normalization techniques need to be applied. Normalization ensures that data is converted into units or to a form that relates it to a chosen standard or baseline and makes it simpler for stakeholders to understand the values. Additionally, normalization increases the transparency as well as the credibility of the final index (Gautam & Singh, 2010).
One common normalization method is to rescale all indicators onto a scale of 0 to 100, with 0 denoting the worst performance and 100 describing the optimum performance. The normalization method chosen in this approach to rescale the data is the “Min-Max-Normalization”. This normalization technique performs a linear transformation of the original data and preserves the relationship among the original data values.
This “Min-Max-Normalization” technique was chosen since it offers a simple and transparent representation of the real world. The difference in the real world between the worst and the best score per indicator is perceived to be equally important and so is the range (Blanc et al., 2008). Therefore, this normalization technique was chosen, since it does not impact the range of the best and worst score to the indicator. This normalization technique also continues to fulfill the requirements set in sub-chapter 4.1.

$$NI_{c,t}^{+} \ - \ Normalized\ Positive\ Indicator$$
$$NI_{c,t}^{-} \ - \ Normalized\ Negative\ Indicator$$
$$x_{i,c,t}^{+} \ - \ Indicator\ i\ from\ Cluster\ c\ in\ Period\ t\ (positive\ influence)$$
$$x_{i,c,t}^{-} \ - \ Indicator\ i\ from\ Cluster\ c\ in\ Period\ t\ (negative\ influence)$$
$$Gx_{i,c}^{+} \ - \ Goal\ Variable\ for\ positive\ Indicators$$
$$Gx_{i,c}^{-} \ - \ Goal\ Variable\ for\ negative\ Indicators$$
$$Xmin_{i,c}^{+} \ - \ Smallest\ Value\ for\ Variable\ x\ over\ all\ Periods$$
$$Xmax_{i,c}^{-} \ - \ Highest\ Value\ for\ Variable\ x\ over\ all\ Periods$$
$$w_{i,c} \ - \ Weight\ for\ the\ individual\ Indicator$$
$$w_{c} \ - \ Weight\ for\ the\ individual\ Cluster$$
$$C_{t} \ - \ Rating\ of\ Cluster\ in\ Period\ t$$
$$ES_{t} \ - \ Environmental\ Rating\ in\ Period\ t$$

The formulas used for this normalization technique are:

(1)

$$NI_{c,t}^{+} = \begin{cases} \frac{x_{i,c,t}^{+} - Xmin_{i,c}^{+}}{Gx_{i,c}^{+} - Xmin_{i,c}^{+}} \times 100, & if:\ x_{i,c,t}^{+} < Gx_{i,c}^{+} \\ 100, & if:\ x_{i,c,t}^{+} = Gx_{i,c}^{+} \\ 0, & if:\ x_{i,c,t}^{+} = Xmin_{i,c}^{+},\ no\ x_{i,c,t}^{+}\ is\ given \end{cases}$$

It can be seen that multiple formulas have been used to normalize the individual indicators onto a unified scale. The reason therefore is, because indicators either have a positive or negative influence on the final rating. For indicators that have a negative influence on the final rating, we need to subtract the result of the formula from 1 to receive a positive value on a scale between 0 and 100.
It can also be seen that there are multiple cases for each of the two formulas. In the case of the positive formula, this has the reason that the value of the to-be-measured indicator in time period t in cluster c can either be smaller than the target variable Xmax, equals the target variable Xmax, or is equal 0 or not reported by the company. If the value of the to-be-measured indicator i in time period t within cluster c is smaller than the target variable, then the “Min-Max-Normalization” has to be used, to see where the company stands between its worst value for indicator i over all measured time periods and the target variable. In case the measured indicator i from cluster c in time period t has reached the desired value of the target variable Xmax, then a normalized value of 100 is assigned. In case no value for indicator i is reported, or the value of indicator i equals 0, then the normalized value for this indicator will be assigned a 0.

For indicators that when they get bigger have a negative influence on the final rating, we receive this formula:

(2)

$$NI^{-}_{c,t} = \begin{cases} 1 - \frac{x^{-}_{i,c,t} - Gx^{-}_{i,c}}{Xmax^{-}_{i,c} - Gx^{-}_{i,c}} \times 100, & if:\ x^{-}_{i,c,t} > Gx^{-}_{i,c} \\ 100, & if:\ x^{-}_{i,c,t} = Gx^{-}_{i,c} \\ 0, & if:\ x^{-}_{i,c,t} = Xmax^{-}_{i,c}, no\ x^{-}_{i,c,t}\ is\ given \end{cases}$$

For the case that increasing the value of indicator i has a negative influence on the final rating, also three different cases have to be used. An indicator, with a negative influence is for example “CO2 emissions”, introduced in sub-chapter 4.4. The first case represents the possibility of the to-be-measured indicator i from cluster c in time period t being bigger than the target variable Xmin. The target variable here is Xmin, since the values for the to-be-measured indicators have to decrease as much as possible (best case reaching 0). In this case, the “Min-Max-Normalization” has to be used to get a normalized indicator on a scale from 0 to 100. In case the value of the measured indicator i from cluster c in time period t is as big as the target variable Xmin, then a normalized value of 100 is assigned. For the third case, a normalized value of 0 will be assigned to indicator i, if indicator i from cluster c in time period t is not reported by the company, or if indicator i is as big as Xmax, the highest value measured over all time periods.
Into the corresponding formula the given values have to be inserted. For variable X the raw value of indicator i of the to-be-measured year needs to be inserted. For the thresholds of Gx, depending on which formula we use, the goals set by the European Commission, the government of the Netherlands, and the SDGs need to be inserted. Here the sustainable development report suggests the use of absolute quantitative thresholds (Sachs et al., 2020). Additionally, did the European Commission set vague goals that should be fulfilled by nations and their inherent companies (European Commission, 2020). E.g.: Water usage should be reduced (Gx(-) = 0) and waste, as well as hazardous waste should be recycled as much as possible (Gx(+) = 100), etc. (European Commission, 2020).
These rescaling equations ensure that all rescaled variables are expressed as ascending variables, which means that higher values denote a better performance regarding environmental sustainability.

4.6 Weighting Method

The following step in setting up a composite index to quantify the environmental sustainability of companies is to assign weights to the individual indicators within the clusters and to assign weights to the clusters which make up the composite index. The weighting method chosen for the composite index was the equal weighting method. The equal weighting method assigns all indicators within the clusters and the clusters themselves the same weights, which in this case would be one divided by the number of indicators/clusters.

A lot of criticism regarding composite indexes is related to the weighting method. Many researchers suggest using the equal weighting method, referring to the dictum “simpler is better”, since it is probably impossible to obtain a unified agreement on weights between researchers and professionals (Rogge, 2012). Therefore the simplest arrangement might be the best choice, which is also confirmed in the sustainable development report from 2020 (Sachs et al., 2020). Sun et al. (2020) and Windolph (2011) agree to the point that the equal weighting method is comparatively the fairest choice since no subjectivity is included. The equal weighting method has the additional advantage that “greenwashing” might be minimized since companies can not apply weights to indicators in a way that advantageously influences their final results (Rogge, 2012).

Additionally, say Blanc et al. (2008) that the “Min-Max-Normalization” in combination with the equal weighting approach is the best default strategy when no scientific knowledge is available for weighing. This approach has also been validated in interviews with experts in the field of sustainability.

The equal weighting approach has next to its offered advantages, also important disadvantages to consider. By providing each indicator with the same weight, the real-world context might not be reflected on a one-to-one scale. Therefore, the relative importance of crucial indicators might be undermined (Badurdeen et al., 2014).

This disadvantage needs to be kept in mind when choosing the equal weighting approach.

Nevertheless was the equal weighting method chosen. The main reasons for this decision were its simplicity, defined in the requirements chapter 4.1, and its preventiveness of subjective bias in prioritizing indicators over others. Last but not least offers the equal weighting approach a solid basis for further research to tweak the weights of the individual indicators.

4.7 Aggregation

Using the equal weighting approach the resulting formula for the individual clusters is:

(1)

$$w_{i,c} = \frac{1}{n_c} \forall i \in \{1, 2, ..., n_c\}$$

Applying the equal weighting approach to the clusters:

(2)

$$w_c = \frac{1}{n} \forall c \in \{1, 2, ..., n\}$$

After assigning the weighting for the individual indicators within the clusters and also weights for the clusters themselves, the formula to calculate the cluster indexes and the environmental sustainability can be set up.

The formula for the clusters was setup in the following way:

(3)

$$C_t = \sum_{i=1}^{n_c} (w_{i,c} \times NI_{c,t})$$

After the values for the cluster has been calculated, the clusters can be added together to receive the final environmental sustainability rating of the to be measured company:

(4)

$$ES_t = \sum_{c=1}^{n} (w_c \times C_t)$$

One the basis of the here created formula was a case study conducted to see how the regarded company performs in terms of environmental sustainability. This case study can be seen in chapter 5.

5. Case study

This case study provides a demonstration of the ESI on the multinational lightning corporation Signify NV. Next to the demonstration, a detailed description is provided, on how the data for this use-case was collected and how it can be upgraded for future usage.

5.1 Data Acquisition

After setting up the formula to quantify the sustainability of companies, data needs to be acquired by the company Little Rocket, to first test and then use the formula to provide value to their customers, using the new service. Since limited data is yet openly available and most companies just started reporting their sustainability data a couple of years ago, data to test this formula is scarce. Data had to be manually collected by analyzing annual and sustainability reports. Additionally, customers have to hand in all their sustainability data they possess to Little Rocket, so a comprehensive analysis can be made. An important addition to the provided sustainability data, is that companies have to explain their data to create a context. There is a lot of room for misinterpretation if the available data has no explanatory report extending it. Companies might acquire or cut off buildings or branches of their company and therefore the index might be influenced massively.

For the following use case data had to be acquired manually. This was carried out by reading and scanning through annual- and sustainability reports of companies. Data regarding the environmental impact of companies was presented in multiple ways here. Data was either structured within tables, or unstructured within text, which made it very difficult and timely to collect all necessary data. This problem will be closer elaborated on in sub-chapter 6.3. Many companies did not report exact values for their environmental data, but only said that they improved or declined, which made it difficult to create a full picture of the individual company.

If data has to be acquired manually, multiple options are at hand to do so. Clients of Little Rocket, wanting to be rated regarding their environmental sustainability, can hand in their data in multiple ways. Surveys, interviews, and audits are common practices here to trade information. An additional way would also be to just hand in the necessary data, supported by a report explaining the individual values, so that there is little room for misinterpretation. In the first instances of this service, data would have to be acquired manually from the reports.

The optimal solution for future research, in the field of sustainability, would be automatic data acquisition. With new technological advancements introduced to the market each day and the continuous development of Big Data Analytics and IoT, this solution appears feasible. Web scrapers can for example scan through annual reports of companies within a small amount of time and extract the necessary data needed for the index. Data can also be collected directly from sensors at the company that is getting measured. Here, IoT offers solutions. Sensors can measure the in- and outputs directly and without any manual work necessary. This automation would offer great advantages over manual work, which brings a lot of errors with it.

For all possible solutions regarding data acquisition, Little Rocket, as well as its clients, need to have a high standard of information quality. Information becomes more important with a rising impact of the results of action (Friberg et al., 2011). Data and the therefore gathered information have to fulfill certain requirements, so that the highest amount of value can be

generated from it. Due to accelerated technological progress and increasing global economic competition, information quality has become a vital aspect of business activities (Michnik & Lo, 2009).
Information quality is not only important for tackling the problem of climate change and an effective business, but also important for raising trust in companies that report these values.
To do this, information has to fulfill a set of requirements, which are widely discussed in literature. Multiple frameworks exist, in which researchers define boundaries that information has to fulfill. Different researchers define different requirements information has to fulfill, or have a different naming scheme for their requirements. Here, the most common quality requirements were chosen in accordance with the quality standards the GRI sets. Accuracy, Balance, Clarity, Comparability, Completeness, Sustainability Context, Timeliness, and Verifiability (Friberg et al., 2011; Zhang et al., 2014; Woodall et al., 2013 & GRI, 2022) are the requirements that have to be fulfilled for information to have a high-quality standard.
Information fulfilling a high-quality standard will lead to high-quality standards of models using this information as a basis.

5.2 A case study on a Dutch multinational company

After sustainability data was acquired within the data collection phase, a use case could be built to present the developed artifact in a real live context.
As already mentioned in the methodology chapter, a conducted use case in this chapter presents that the developed artifact tries to solve instances of the research problem. Within this use case the individual steps of the rating procedure are made visible, as well as the final result that tries to describe the environmental sustainability of a company for the individual year the data was taken from.
The chosen company for this use case is Signify, a multinational lighting corporation from the Netherlands. Data was taken from the years 2015, 2019, 2020, 2021. The year 2015 was chosen as a reference year to compare Signifies recent reported data to. 2015 was chosen as a reference year, since this is one of the first years where Signify reported their environmental data in a complete and useful manner.
As described in sub-chapter 4.5, all the acquired environmental company data from manually reading annual reports had to be normalized. For this the formulas presented in sub-chapter 4.5 were used. For data that was not made available by the company and where the company did not give a reason why this data was not provided, a rating of 0 was issued.
The normalized values were summarized in table 7 to provide a quick and simple overview for the individual stakeholder. In addition to the ratings of the individual indicators, these ratings were aggregated to cluster ratings, which are presented at the bottom of table 7. Next to the cluster ratings, is a sustainability rating for the individual year provided, which was calculated by aggregating the cluster ratings for the specific year.
To collect the company data in one location, all the data was filled into excel files. By using the calculating excel functions, the individual normalized ratings were calculated.

Emissions	CO2 Emissions (Scope 1-3)	0	50,28	54,75	55,59
	NOx Emissions	0	0	0	0
	SOx Emissions	0	0	0	0
Water	Water Pollution/ Discharge	0	0	0	0
	Water Recyled	0	0	0	0
	Total Water Usage	0	46,09	44,55	18,22
Energy	Renewable Energy	58	94	100	100
	Own Energy	38	34	49	89
	Total Energy Usage	0	25,47	28,49	30,37
Waste	Recycled Waste	58	94	100	100
	Total Hazardous Waste	0	62,08	70,31	69,57
	Total Waste	0	19,11	27,11	2,67
Emissions Cluster		0	16,76	18,25	18,53
Water Cluster		0	15,36	14,85	6,07
Energy Cluster		32	51,16	59,16	73,12
Waste Cluster		19,33	58,40	65,81	57,41
Sustainability		12,83	35,42	39,52	38,78

Table 7: Signify's normalized environmental values

The values presented in table 7 show how the individual indicators, as well as clusters, are rated for the individual years. To create a better overview for stakeholders of different kinds, a graphical presentation is provided in figure 5. This representation was also created using different excel functions. Within this graphical presentation, a better overview is offered of the development of Signify regarding their environmental sustainability reporting and their progress towards the set goals by the UN and the EU.
Within this overview, two types of graphs have been used. On the one hand, bar charts describe the individual rating of the clusters for each year. On the other hand, a line chart describes the aggregated cluster ratings and therefore the sustainability rating of Signify for each individual year, as well as its development over time. These graphs offer a good overview of which clusters have a positive or negative influence on the final rating, so companies know, by comparing their results, where they have to improve. Additionally, a development is nicely presented, so stakeholders of different kinds know if the underlying company addresses sustainability issues.

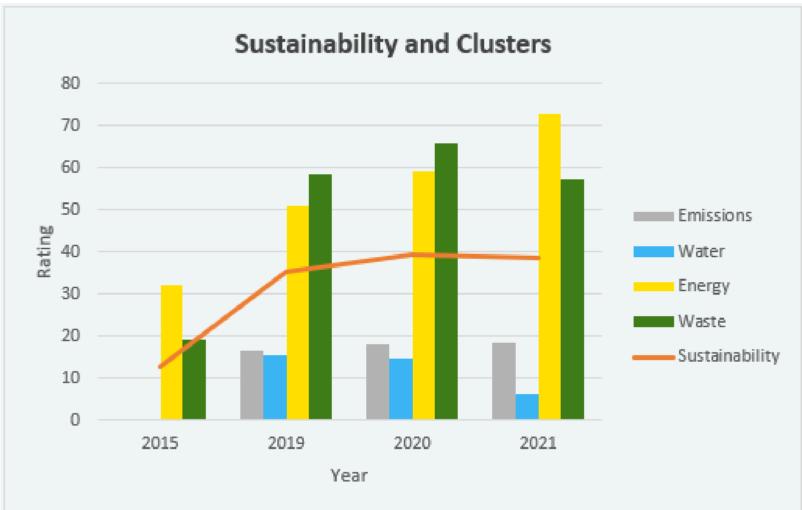

Figure 5: Graphical visualization of Signifies progress from 2015 until 2021

Both presentations offer a critical advantage. By normalizing all values onto a unified scale and presenting them as clusters, as well as aggregated sustainability ratings, comparability within the company over multiple years, and with other companies is possible. Comparability is being regarded by policymakers, as well as experts as one of the most important features of an ESI and therefore this provides a good solution to tackle this problem. Comparability within the company over multiple years is of major importance here. Companies can compare their current results to their previous ones, so that they always thrive to become more environmentally friendly and not just better than their competitors.

Both presentations, table 7 and figure 5 have to be analyzed while considering their underlying context. Data on itself will only offer half a picture.
Neither table 7 with the data values, nor the graphs in figure 5, offer a complete picture of how the company tackles environmental sustainability. A report, describing and extending these presentations needs to be provided, so stakeholders can understand what the individual values mean and why a certain development took place. For example is it possible that companies acquire new branches, or take over other companies, which could result in a drastic increase in the to-be-reported values and therefore influence the environmental rating of that year.

Figure 6 provides a sustainability index for 16 out of the 43 listed large-cap companies on the Euronext stock exchange in Amsterdam. Here companies that are only listed in the Netherlands are taken into consideration.
In total were 22 companies listed on the Euronext stock exchange in Amsterdam analyzed, but only 16 out of these 22 companies reported enough data within their annual- and sustainability reports to build an index on. 6 out of the 22 analyzed companies were left out, since too little data was reported, which introduced too much bias because of missing values. To reduce bias, by not reported values, within the index as much as possible, only companies that received a rating in three out of four clusters were included. Another criteria to include companies into this index was that they need to be listed as large-cap companies on the stock exchange. This was because large-cap companies had the highest percentage of reporting environmental data. Additionally are companies with a large capitalization the first ones that need to report their environmental data regarding to the laws of the EU.
By analyzing each of the 16 companies and rating their four clusters, as well as their total environmental sustainability, the average of all companies for each year could be taken. Therefore, an index could be calculated. The companies are equally weighted within this index, which means that their capitalization size has no weighting impact on the index. By calculating an index for Dutch companies, an additional possibility is created to compare individual companies. Companies can be compared against the average values, so stakeholders can see how individual companies perform against the average (figure 6).

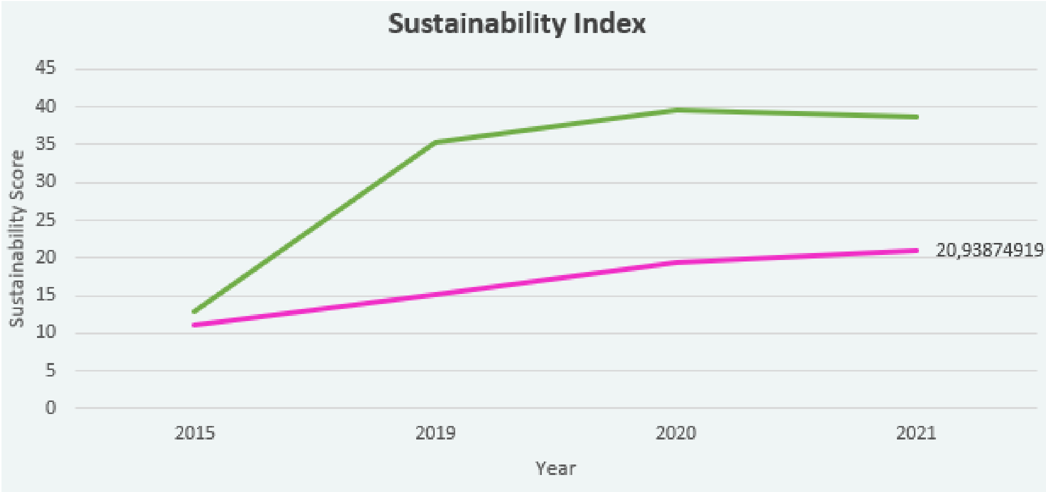

Figure 6: Sustainability index for 16/45 large cap companies of the Netherlands

An additional possibility to offer comparability is to utilize open data sources. Open data offers publicly available sources to acquire data, which can be used to make comparisons and create more insights into the information at hand. In the given use case, it is due to open governmental data possible to compare Signifies progress in cutting emissions to the overall progress of the Netherlands. Figure 7 offers a nice presentation, of how Signify compares to the Netherlands, on all the emissions indicators.

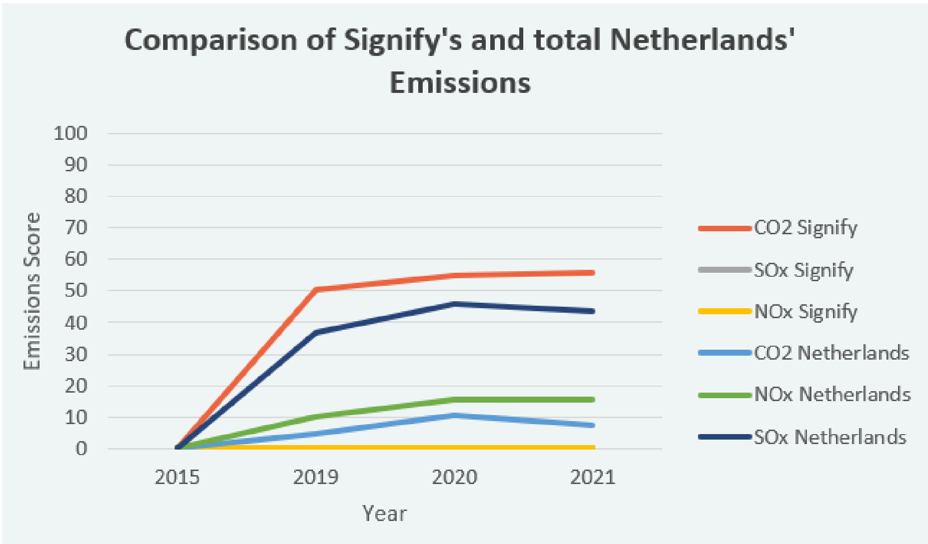

Figure 7: Signifies data on emissions compared to the Netherlands emissions data

To compare individual company data to open governmental data of nations, multiple databases were scanned through and analyzed. Therefore open databases from the European Union, as well as open data from the Netherlands were scanned through. What was noticeable was that environmental data was scarce and difficult to find. Which might be due to the novelty of the topic and due to just recent advances in the field of IoT and other technologies, which are able to measure and calculate estimates for in- and outputs.

As mentioned in earlier chapters, expert interviews were conducted to validate the individual steps, as well as the graphical representations, and the ESI. During these interviews most of the presented results were deemed as useful to address the current issues with environmental ratings. Additionally, points of discussion were addressed and critics implemented. These points of discussion as well as the critics will be more closely presented in the upcoming discussion chapter.

6. Discussion

This chapter analyzes the similarities and differences to existing indexes, and shows how the proposed solution offers advantages over existing methods of quantifying environmental sustainability. Following up, the proposed solution is evaluated, based on the requirements set in chapter 4. Additionally, limitations are presented, which offer starting points for future research.

6.1 Comparison with other Indexes

In earlier chapters of this research, limitations within already existing ratings regarding the environmental sustainability of companies have been introduced, in addition to the problems these limitations produce. By conducting expert interviews, existing environmental sustainability ratings have been discussed and compared to the here proposed solution. Within these interviews, multiple typical characteristics and differences could be uncovered.

No rating measuring the environmental sustainability of companies focuses yet on the four key indicators, mentioned in scientific literature, water, waste, emissions, and energy. A key characteristic of this index is its simplicity. Therefore, this index also allows companies, outside of the industrial sector, to be measured regarding their environmental sustainability. Additionally, this index is also applicable to companies in other countries outside the Netherlands. The simplicity of the construction of this index also allows for extending it with additional indicators, so that it can be used to measure sustainability on individual needs. Which was also confirmed during multiple interviews.

This characteristic has a lot in common with the Sustainable Development Goals set by the UN since these are also applicable to many different sectors within an economy. A major difference between the developed index within this research and the SDGs is that here the environmental sustainability of companies can be measured without the necessity to compare it against others to see if one performs well or not. Measuring environmental sustainability on a scale of 0 to 100 offers stakeholders and investors a clear picture of how well the company performs in regard to the set goals.

Another critical characteristic of the here developed index is the quantifiable nature of the indicators and the overall index. By only including numeric variables within the index, subjectivity can be reduced while measuring these indicators. The quantifiable nature of this index also offers companies the option to measure their environmental sustainability themselves in-house, and therefore only need to get certified or audited by a third party, like Little Rocket.

Supplementary, allows this quantification the desired comparability, not only between companies, but also within a company over time. Stakeholders and investors can assess a company's environmental sustainability against other similar companies to base their investment decisions on. The quantifiable nature of this index therefore has advantages over other existing ratings. The subjectivity of existing ratings defines a major critic towards such environmental ratings. Subjectivity allows for changes and therefore it is difficult to create a standard, every company can be compared on.

Additionally, can a timeline be drawn on how the company performs over multiple periods regarding their overall environmental sustainability and also regarding their individual clusters. This allows for more comparability, not just against other companies, but also within the company over multiple time periods.

The addition of open data sources, to provide more comparability against sector averages and thresholds also offers new features, which can not be found in many other ratings. Therefore, this ESI provides an extensive overview of the current situation within an economy. The chosen design of this rating and the comparability against open environmental data sets, tackle a critical pain point many people and literature currently have with existing ratings. The reduction of subjectivity and the chosen indicators, applicable to all sectors, may offer a useful design for environmental ratings. Creating a standard for everybody and therefore allowing comparability and therefore a better understanding by stakeholders, raising their trust. This also underlines the findings made during the expert interviews, mentioned at the beginning of this sub-chapter. By reducing subjectivity and creating a unified rating method, based on quantifiable indicators, the major critical points of other ratings can be addressed.
Within the scientific literature, this research might also offer new reference points regarding the quantification of environmental sustainability for companies.

6.2 Evaluation

For the evaluation of the developed ESI a bottom-up approach has been used. Therefore expert interviews have been conducted, to validate that this index fulfills the set requirements in sub-chapter 4.1, on top of being applicable to a real-life context.
By conducting multiple expert interviews, the viability of the developed index for rating the environmental sustainability of companies was confirmed, as well as multiple problems this index addresses were uncovered. Additionally, were multiple future possibilities and advances uncovered, which will be closer addressed in sub-chapter 7.2.
From the perspective of multiple stakeholders, this index creates additional transparency regarding the environmental sustainability of companies. Additionally, this index not only allows executives of companies to measure the environmental sustainability of their company, but also offers a basis for decision-making regarding sustainable development and allows them to make decisions on improvements for the future. This index could therefore lay the basis for company executives to acknowledge problem points within their environmental sustainability practices. On top of that, also create measures to tackle these problem points. Building up on this, this index allows companies to make advances regarding sustainable development and therefore offers them advantages over competitors and in general within the market. In addition to this, this rating method discovers key indicators which are not measured or reported yet and can therefore offer optimization to the current environmental development of the company. The simplicity of this rating method also enables stakeholders with little knowledge of environmental sustainability to see where optimization is possible, which is also supported by the transparency of the rating methodology.
Therefore this rating methodology fulfills the first requirement R1. of describing on its own the current state of a company's environmental development. The second requirement R2., regarding the applicability to other companies within the spectated industrial sector and with adjustments also to other sectors could also be seen as fulfilled. The chosen indicators are regarded by governments as well as NGOs and literature crucial to tackle the problem of climate change and therefore environmental sustainability.

Therefore this rating should be applicable to all companies within the industrial sector and also to companies within other sectors. Because of the simplicity of the normalization and weighting methods, indicators can easily be added and withdrawn from the formula, to make this formula applicable to companies within other circumstances, depending on individual needs.

The simplicity, already mentioned in the first two requirements, comes also into play within the third requirement R3. The normalization and weighting methods chosen in this research transform multiple variables of different scales into values of one unified rating scale. This allows a simple and transparent overview of how the values have been derived and how they stand in comparison to each other. Which received a lot of confirmation during the interviews. Due to the quantitative nature of this index, for all indicators being numeric values, comparison of company values over time, as well as cross-comparability between companies is possible. Therefore requirements R3. and R4. could be seen as fulfilled.

Requirement R5. offers some points of discussion, since it requires quantitative indicators, which are feasible to be measured. On the one hand, this index consists of only quantitative indicators, but on the other hand, it can not be guaranteed that all companies have the ability to measure these indicators. Companies might be missing necessary funding or the know-how of measuring these indicators. Therefore requirement R5. can not be regarded as fulfilled. This was also confirmed within the expert interviews. Here it was said that if companies do not report their data regarding one of the included indicators, they need to explain why this is. On the one hand, could privacy reasons prohibit the reporting of an indicator, and on the other hand can technical and knowledge capabilities be missing. In the future, this problem will play, due to the increasing importance of IoT, a significantly smaller role (Feroz et al., 2021).

Requirement R6., which says that the index and its composition should be understandable, goes hand in hand with the requirement for simplicity. For the normalization, along with the weighting and aggregation, simple methods were chosen in addition to a limited number of included indicators, so that an understandable and transparent way of interpreting the result was layed.

Since the most referenced indicators within literature, as well as within other frameworks, were chosen to build the here-developed index on, requirement R7. could be regarded as partially fulfilled. During the interviews this was confirmed by the experts, saying that the most relevant clusters, as well as indicators regarding environmental sustainability were included. This has to be seen critically, since depending on different variables, circumstances, and branches the indicator set might have to change. Therefore it can not be confidently said that requirement 7 is completely fulfilled.

By adding additional indicators to the composite index, it has to be considered that the weighting has to be adapted too. In the case of adding only one indicator to a single cluster, this cluster would have a different weighting scheme and therefore influence the final indicator. To overcome this bias, the same amount of indicators have to be added to all clusters. Adding additional indicators raises the effort that has to be put into the index and therefore raises costs. Companies need to consider if they want to have a more detailed and fine-grained rating, but which will also incur more costs to their books.

6.3 Limitations

This research provided, next to some valuable insights, also some limitations regarding the quantification of environmental sustainability of companies within the European Union. This was also made visible during the expert interviews.
The biggest limitation regarding this index might be the normalization, as well as the weighting approach. Assigning weights to the indicators within an environmental index is a big point of discussion in the field of sustainability, as well as in literature, and researchers can not seem to agree on one common approach (Poveda & Lipsett, 2011; Zhou et al., 2012; Böhringer & Jochem, 2007 & Rogge, 2012). Even though the equal weighting approach, chosen in this research, receives a lot of support, it still has to be seen with a lot of criticism, since it might not reflect the real world on a one-to-one scale. Next to the weighting scheme, the normalization method receives, next to attention, also a lot of skepticism in literature. Different approaches receive support from different researchers. The here chosen approach of the “Min-Max-Normalization” seems according to researchers to be a precise combination with the equal weighting method. More research has to be put into this to find optimization points within the normalization method. As already mentioned in earlier sub-chapters, it is important to minimize subjectivity as much as possible. Giving higher or lower weights to indicators, without carefully analyzing their relevance compared to other indicators, might favor or disfavor companies. By choosing the “Min-Max-Normalization” and the equal weighting approach for this study, subjectivity was, at the cost of real-world representativeness, reduced. The cost of real-world representativeness has to be kept in mind. Not representing the real-world perfectly, might result in actions with smaller impact taken to address current problems with sustainability.
Another critical limitation point with this index is the limited amount of available data points. Companies only started reporting environmental data a couple of years ago and therefore only a limited amount of yearly environmental data is available. This introduces a lot of bias into the model since no sensitivity analysis or correlation can be sufficiently conducted. Additionally, extreme points do have, because of the limited amount of available data, a big influence on the final resulting index. More data needs to be made available over time to better optimize this index, as well as mathematical models, to find correlations and to minimize the impact of extreme values. Testing is of major importance here, to further improve the rating method. Without constant testing, the rating method and indicators might not correctly reflect the problems anymore.
Next to the extreme values, is the missing of to-be-reported values also posing a limitation to this index. Indicators that were not reported by companies, without providing a reason for it, received a value of 0. This poses a big influence on the final index and might make a company seem to perform worse than it actually is. This big influence can also be explained due to the limited number of included indicators, since this way a single indicator might have a significant impact on the final result. To overcome this limitation, one possible solution would be to include more indicators, to make the impact of a single indicator less severe. Another solution would be to make the companies more aware of measuring and reporting all necessary and mandatory indicators. This would not only favor the individual company, since no values are missing, but also provide the rating method with more data to be tested on.
As mentioned, to reduce the influence of all individual indicators, more indicators could be added. Here might the weighting scheme introduce a problem, since the same amount of indicators has to be added to all clusters, to not bias the weights of the individual indicators

within a cluster and therefore also the final result. Adding to some clusters more indicators than to others, would make the impact of the indicators, within the cluster with the bigger amount of indicators, less severe than to others. This would bias the general equal weighting method and therefore also the final rating.
Building upon this, selection bias might influence the final result of the developed index (Boffo et al., 2020). Even though a thorough literature review and a framework analysis were conducted, more research has to prove if the selected indicators have the most influential impact on the final result. Another limitation regarding the selection of indicators is the fact that the indicator of own energy production has been included. This has the reason that other indicators regarding energy usage were directly dependent on each other and therefore might result in double counting of the same values. This has to be viewed critically since this is the only indicator that has not been taken from the literature. To prevent a biased result of the index, not representing the real world situation, more interviews and more research have to be conducted to confirm that this indicator is important for a more sustainable business.

Adding to these, the fact that companies measure and report their waste disposal and water pollution in different units, also in carbon dioxide emissions emitted, poses another limitation. Companies that measure and report their waste disposal and water pollution in CO_2 emissions might receive a biased rating since these emissions might already be reported in their air pollution reporting. To overcome this, a standard has to be developed on how companies have to report so that no double counting might be available.
Additionally, it is difficult for many companies to measure their waste and water recycling rate. Many companies do not recycle water and waste themselves and therefore need to trust the company dealing with their water and waste disposals. Without clear, trusted values, provided by either the disposal companies, or by the here measured companies, the current problems regarding environmental impact will not be targeted precisely.
A further limitation might be that this topic is relatively new and therefore knowledge might still be limited. With time this topic will evolve since more and more research will be put into this.
Next to these limitations, the Covid-19 pandemic also presents to have a big impact on the sustainability rating of companies. During the data collection, it was noticeable that many companies had a better impact on the environment during the pandemic year of 2020 than in the years before or after. Especially after the pandemic year of 2020, it is noticeable that most of the companies had a worse environmental performance than during or before the pandemic. This could be due to the reason that work that should have been done during 2020 was postponed to 2021, so companies had to produce, dispose, etc. more than they normally would in a year.
All in all more environmental company data needs to be collected to optimize this index and to better see how this index compares against its competitors in the field. Additionally provides the small amount of expert interviews limitations regarding the evaluation of the results. Within each interview at least one additional point was discovered which could be implemented into this index. This shows that a lot of subjectivity is included in the field of constructing composite indexes and more expert interviews need to be conducted to confirm the results from the first few interviews. Without testing this rating method often and optimizing it with experts, the current problems of climate change and the environmental impact of companies will not be tackled as well as they could be.

7. Conclusion and Further Research

The final chapter answers the proposed research question, provided in chapter 1, and provides starting points for future research in upgrading the here developed ESI.

7.1 Conclusion

"What gets measured, gets done" (Klaus, 2015). Using this quote as a baseline for the here presented approach of building an index to measure the environmental sustainability of companies, it is possible to say that by introducing such measurements, management teams of companies are offered new possibilities in developing strategies and procedures to tackle their environmental impact and the problem of climate change. Complete and trustworthy measurements are building the key component of the here presented environmental sustainability index. Therefore the proposed research question can be positively answered, that this unified ESI, based on indicators from scientific literature, can contribute to offer a solution to current issues with environmental sustainability ratings within the European area. Lack of standardization, therefore also a lack of transparency, and trustworthiness, as well as too much subjectivity were described as the major issues in assessing the environmental state of companies. These issues were tackled and resolved, by designing an index, based on indicators, selected from scientific literature. These indicators cover a wide range and are applicable to many sectors. Additionally, to reduce subjectivity and therefore also partially reducing the issue of "greenwashing", an equal weighting and "Min-Max-Normalization" were chosen. Building up on this, the quantifiable nature of all indicators, as well as the index itself, reduces subjectivity. No personal opinion is required to judge if the performance of an indicator is good or bad, since only concrete numbers exist.

Currently, measurements on environmental impact pose a big problem in the field, but with new stricter regulations from the European Union coming into force, as well as the increased use of information technologies, such as big data analytics, IoT, and AI, advances are on the horizon.

For large companies, there still exists a lot of room for improvement to reach a higher environmental sustainability score, which would not only benefit the environment but also stakeholders and clients of these companies, since the sustainability movement is in full swing. Due to the simplicity, and therefore understandability of the here presented index, stakeholders, investors, and clients are being offered an easy-to-understand and comparable value. The simplicity also tackles the problem of ratings being difficult to understand. Stakeholders can interpret the rating of a company, without the need of having profound background knowledge. Comparability plays, as said earlier, a crucial role. This attribute received a lot of criticism in the past since clients, investors, and stakeholders want to understand where the underlying company stands in comparison to competitors or to the set goals by governments and authorities.

Next to the important attribute of being comparable, the presented index offers a transparent picture of important indicators, from literature, to build the index on. By using standardized and widely accepted indicators, the index can help to ensure that companies are being evaluated on a level playing field. This can help to prevent companies from manipulating their performance by selectively reporting only their most favorable indicators (greenwashing).

In addition to that, by regularly updating the index and making the data publicly available, companies can be held accountable for their environmental performance, and consumers and investors can make informed decisions about which products and services to support.
In sum, the here developed ESI helps to improve the current state of measuring environmental sustainability of companies within the European region. Tackling the currently biggest problems, of ratings not being comparable, trustworthy and standardized, this rating method offers a solution to improving the current state of rating environmental sustainability within Europe. By addressing the current problems and reducing subjectivity, through standardization, this rating method can lead to a more sustainable future.
This is just the first step of building an ESI, to measure the sustainability of companies. More work has to be conducted towards the construction of the index to further evolve and upgrade it.

7.2 Further Research

As can be taken from the discussed limitations of the developed ESI, there is still some room where more research could further evolve the environmental rating and therefore open up more benefits for multiple sorts of stakeholders. More validation from experts will be needed to reduce the current biases, as well as practical testing to confirm that this method also works in a real world context. In addition to the testing in a real world context, with time more data will need to be made available by companies and NGOs to create better models and test correlations between the result and the individual indicators. With more data becoming available it can also be tested if other indicators or indicator combinations might suit the ESI better. This might in the first place be done for the indicators that have been most referred to in this literature review. In general more research has to be put into the selection of indicators, as well as the number of indicators to include into this ESI. This is due to the fact that a lot of frameworks and ratings use a different number of indicators.
Next to using more data to test the formula and the indicator combination, the data acquisition can further evolve. The current manual procedures can be upgraded to automatic processes, which will cause fewer errors in the reading of data. Technological advances can be of great value here, since these enable us to acquire more data faster than humans do manually.
In addition to testing the validity of indicators, more research might have to be put into the weighting method of the index. With more testing of which indicators have a bigger influence on the final rating, the weighting scheme can be changed, so that indicators that have a higher influence, receive a higher weight.
In addition to further researching the weighting method, more research can be conducted towards additional variables, such as time. Time might also play a significant role towards reaching the set goals by the EU. For example, time might have a higher influence on the final rating, the closer the deadline for reaching the desired goal is.
Another possible point for future research could be to study if a comparable value for environmental sustainability offers advantages in terms of raising competition between the individual companies. Having good environmental sustainability should be seen as a goal everybody should fulfill and where individuals help each other with reaching this goal.
Summing up, this index also needs to be constantly checked and updated, since environmental requirements might change due to new governmental constraints and regulations.

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9. Appendix

Appendix A

Description of KPIs

Total Scope 1-3 Emissions

A company's emissions are classified into three scopes. Scope 1 and 2 are mandatory to report, whereas scope 3 is voluntary and the hardest to monitor. However, companies succeeding in reporting all three scopes will gain a sustainable competitive advantage.

Scope 1 emissions are direct emissions from company-owned and controlled resources.

Scope 2 emissions are indirect emissions from the generation of purchased energy, from a utility provider. All GHG emissions released in the atmosphere, from the consumption of purchased electricity steam, heat and cooling.

Scope 3 emissions are all indirect emissions, not included in scope 2, that occur in the value chain of the reporting company.

Total NOx Emissions

This KPI describes the total amount of nitrogen oxides emitted, which can be a significant source of air pollution.

Total SOx Emissions

This KPI, describing sulfur oxides, is a source of air pollution and is regulated in most markets.

Total Energy Use

This KPI describes the total amount of energy used by a company measured in KW/h.

Renewable Energy Usage

THis KPI describes the percentage of renewable energy used by a company.

Own Energy Generation

This KPI describes the percentage of own generated energy, and not taken from the energy grid, to power own operations.

Total Waste Generation

This KPI describes the total amount of non-hazardous waste generated by a company, measured in tonnes.

Total Hazardous Waste Generation

This KPI describes the total amount of hazardous waste generated by a company measured in tonnes.

Waste Recycled

This KPI describes the percentage of waste recycled of the total amount of generated waste.

Total Water Use

This KPI describes the total amount of ground/freshwater used for production processes.

Water Pollution/Discharge

This KPI describes the amount of water that is being released back to nature in liters.

Water Recycled

This KPI describes the percentage of water being recycled after use from the total amount of used water.

Appendix B

\	Literature																		
Variables	Poveda et al. (2011)	Semenova & Hassel (2014)	Muñoz-Torres et al. (2018)	Aouadi & Marsat (2016)	Krajnc & Glavič (2005)	Gebhardt & Kefer (2019)	Bassen & Kovacs (2008)	Rusche et al. (2021)	Bardurdeen et al. (2014)	Veleva & Ellenbecker (2001)	Garbie (2014)	Gani et al. (2021)	Labuschagne et al. (2005)	Jiang et al. (2019)	Gautam & Singh (2010)	Li et al. (2012)	Stanistsas et al. (2021)	Seuring et al. (2003)	Helleno et al. (2017)
energy usage	x	x				x		x	x	x		x	x	x	x	x		x	x
energy efficiency		x					x		x			x		x	x	x	x		
renewable energy usage							x	x	x	x	x	x				x	x		
energy usage from non-renewable sources									x			x		x	x				
emissions	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x
emission of acid gases												x							
ozone depletion												x							
pollution prevention		x																	
water usage		x				x		x	x	x		x	x	x	x	x	x	x	x
water pollution	x								x		x	x		x	x	x	x	x	

water recycled									x		x	x			x	x			
non-hazardous waste produced	x	x					x	x	x	x		x		x		x		x	x
waste recyclement											x	x		x					x
hazardous waste	x	x						x	x	x	x	x				x			
reuse of hazardous waste									x										
fossil fuel usage	x	x																	
natural resource use	x			x		x		x	x				x		x		x		x
material consumption		x				x		x	x	x		x		x		x		x	x
hazardous materials used												x							
recycling of own materials		x						x				x		x					x
use of recyclable materials	x							x	x	x		x		x		x		x	
use of packaging materials									x										
use of recycled packaging materials									x	x		x							

noise pollution	x								x										
light pollution	x								x										
heat pollution									x										
overshadowing	x																		
transport and cycling materials	x																		
hazardous events					x							x							
environmental policy		x					x			x	x	x					x		
lifecycle of products						x	x												
biodiversity						x		x			x	x					x		
land use											x	x	x						
assessment framework			x	x								x							
regulatory violations								x	x		x	x							
environmental budget											x	x							
Product-end-of-li fe									x	x		x		x					

Appendix C

Search Terms used for this research and their found results:

Google Scholar

Environmental Rating: 4020000
Nachhaltigkeitsindex von Unternehmen: 173000
Environmental Sustainability index for dutch companies: 189000
Environmental Sustainability index for materials industry: 2190000
Global warming: 2830000
Resource scarcity: 2130000
Environmental sustainability: 5730000
Social sustainability: 5630000
Economic sustainability triple bottom: 195000
Quantifying environmental sustainability over time: 996000
Environmental indicators for business: 3990000
Environmental performance index: 7170000
Environmental sustainability index for construction companies: 1040000
Environmental reporting AND netherlands: 3430000
Sustainability: 4140000
Data analytics AND environmental sustainability: 348000
Information quality: 8490000
Environmental sustainability indicators: 3590000
Nachhaltigkeitsindizes der fertigungsindustrie: 7
Corporate social responsibility: 2940000
Corporate social responsibility directive: 152000

Scopus

Environmental_sustainability AND companies: 1910
Measuring AND environmental_sustainability AND companies: 51
Assessment AND environmental_sustainability AND equal_weighting: 3