Doctoral thesis

Integrated Investing

How to integrate environmental impacts in investment processes of companies.

Technische Universität Darmstadt (D17)
Faculty of Civil and Environmental Engineering

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Approved doctoral thesis with the intention to achieve the degree Dr. rer. pol.

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Oh, Mother Earth,
With your fields of green
Once more laid down
by the hungry hand
How long can you
give and not receive
And feed this world
ruled by greed
And feed this world
ruled by greed.

Oh, ball of fire
In the summer sky
Your healing light,
your parade of days
Are they betrayed
by the men of power
Who hold this world
in their changing hands
They hold the world
in their changing hands.

Oh, freedom land
Can you let this go
Down to the streets
where the numbers grow
Respect Mother Earth
and her healing ways
Or trade away
our children's days
Or trade away
our children's days.

Respect Mother Earth
and her healing ways
Or trade away
our children's days.

Mother Earth (Natural Anthem)

Neil Young, 1990

The results, opinions and conclusions of this dissertation are not necessarily the same as the Volkswagen Group.

Abstract

Environmental management systems aim to ensure legal compliance on the one hand and continuous improvement of environmental performance on the other hand. Due to its cross-sectional character, environmental management systems affect all parts of the organisation. Another cross-sectional system is the management accounting system which intends to support ex-ante internal management decision-making processes. The overlapping part of both systems deals with environmental issues in business planning processes and is commonly referred to as environmental management accounting. However, the field of environmental management accounting is still young and corresponding methods are currently under development.

Besides financial goals, companies increasingly start formulating strategic environmental goals. However, the management and control of these goals remains a challenge. Thus, the formulation of strategic environmental goals in qualitative terms limits their management and control. On the other hand, the systematic integration of strategic environmental goals in management accounting processes, such as investment appraisals and decisions, represents a research gap.

Therefore, this thesis aims to develop a method that is able to systematically integrate financial and environmental data in investment processes to support the achievement of strategic environmental and financial goals of companies. This new integrated investing method intends to provide a sufficient degree of scientific quality on the one hand and practical applicability on the other hand.

In context of this thesis, a deficit analysis assesses reasons why current methods of environmental management accounting have not established as common business practice so far. During the first part of the subsequent method development a set of seven requirements is composed. On basis of these requirements additional methods of environmental management and management accounting systems are evaluated resulting in a final set of three approaches representing the basis of developing the new integrated investing method. After developing and describing the new integrated investing method, the method is applied in seven case studies within the Volkswagen Group. This method application verifies the method's practical applicability as well as its ability to manage and control strategic environmental and financial goals.

In conclusion, this dissertation contributes to the development and application of a new integrated investing method that aims to ensure a sufficient degree of scientific quality and practical applicability. With the help of this method, it is able to systematically integrate environmental impacts in investment processes of companies in order to manage and control the achievement of strategic environmental and financial goals.

The recommendations for future research address the limitation of the Ecological Scarcity Method, on which the integrated investing method is based, as well as the application of the new integrated investing method in contexts outside the Volkswagen Group.

Preface

This thesis evolved in context of my time as a doctoral candidate at the Volkswagen Group Research Environmental Affairs department, in which I had the pleasure to support the environmental management team. During the first few months, while I was searching for an appropriate topic for my dissertation, the team was faced with an increasing amount of enquiries. These enquiries requested a method for a decision-making process that balances financial and environmental aspects. While the financial costs and benefits of an investment could be identified and quantified, decision-makers were uncertain about the quantification of environmental impacts associated with the investment.

The more my colleagues and I immersed into this topic, the more controversial and complex were the associated discussions, which finally led us to the necessity for a sound academic but also pragmatic solution in form of my dissertation. Hence, this thesis addresses environmental management and management accounting professionals, who are faced with similar enquiries on the one hand and the scientific audience on the other hand, which is cordially invited to discuss my proposed method.

This thesis would have never been written without the support of my family, friends and colleagues. First of all, I am very grateful to Judith for her endless support and belief in me, not only during the time of my dissertation, but also for encouraging me in whatever I have done so far – be it studying and working abroad or all of my additional projects, which mostly take place far away from our shared home. In this context, I am especially pleased to count on my grandparents, parents and my sister, who constantly believe in the success of my projects, which always encourages and motivates me.

I have also not forgotten the inspiration of Tim Kaske, who encouraged me to even think about the option of writing a dissertation. At that point of time, writing a dissertation seemed to me as an unreachable goal. Without his inspiration, I would have never applied for the job offer as doctoral candidate at the Volkswagen Group.

During my time as doctoral candidate, I had the pleasure to work together with lots of bright colleagues, who took the time to listen to my thoughts and who did not hesitate to provide valuable and constructive feedback. In this context, I am especially thankful for the constant help of Steffen Wellge in form of time, guidance, motivation, trust, creativity, open and honest feedback. Without Steffen's support, I would simply not have been able to finish my dissertation in three years' time and working on my dissertation would not have been that much fun.

Furthermore, I was supported by my supervisors, Günter Damme, Dr. Liendel Chang and Gerhard Mogg, who enabled me to present my dissertation to broad audiences within the Volkswagen Group Research but also in context of external scientific conferences.

I am additionally thankful for various colleagues who supported me in conducting the case studies: Kai Schweingruber, Kai Jaekel, Christian Pressel, Marius Rode, Markus Meyer, Dr. Stefan Brinkmann, Dr. Jens Asche, Marcin Grochowski, Stefan Rose, Erhan Icten, Malte Gebler, Volker

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Last but not least, I am very grateful for the support of my doctoral supervisor Prof. Dr. Liselotte Schebek and my second supervisor Prof. Dr. Edeltraud Günther, who not only agreed to supervise my thesis, but also took their time to provide constructive and valuable feedback, which helped me to keep focused and to solve all emerging issues.

If you have comments or if any questions remain unanswered at the end, please do not hesitate to send me an e-mail:

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September 2015

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2011 – 2012: Master of Science (M.Sc.) in Sustainable Business at Manchester Metropolitan University Business School in Manchester, United Kingdom

2012 – 2015: PhD Student at Group Research Environmental Affairs Production at Volkswagen in Wolfsburg, Germany

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ABC	Activity-based Costing
ARR	Accounting Rate of Return
BAFU	See FOEN
BAT	Best available technology
Capex	Capital expenditure
CHP	Combined Heat and Power Station
CML	Centrum voor Milieukunde Leiden
CPI	Corruption Perception Index
CV	Compound Value
CVM	Contingent Valuation Method
EF	Ecological Footprint
EFANRW	Efficiency Agency of North Rhine Westphalia
ELU	Environmental Load Unit
EMA	Environmental Management Accounting
EMAS	European Eco-Management and Audit Scheme
ENPV	Ecological Net Present Value
EP	Eco-Point
eP&L	Environmental Profit & Loss Account
EPM	Eco-rational Path Method
EPP	Ecological Payback Period
EPS	Environmental Priority Strategies
EROI	Ecological Return on Investment
ESM	Ecological Scarcity Method
EU ETS	European Union Emissions Trading Scheme
EURIBOR	Euro Interbank Offered Rate
EVIL	Environmental Impact Load
FEM	German Federal Environment Ministry
FOEN	Swiss Federal Office for the Environment
ICV	Internationaler Controller Verein
IFAC	International Federation of Accountants
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
ISO	International Organization for Standardization
JIT	Just-in-Time
KEA	Cumulated Energy Demand
KPI	Key Performance Indicator
LCA	Life-cycle assessment
LCC	Life Cycle Costs
LIBOR	London Interbank Offered Rate
MADM	Multiple Attribute Decision-Making

MCS	Management Control System
MEJ	Ministry of the Environment Japan
MIPS	Material Intensity per Service Unit
MJ	Mega joule
N_2O	Nitrous oxide
NGO	Non-Governmental Organisation
Nm^3	Norm cubic metre
NPV	Net Present Value
OEM	Original Equipment Manufacturer
Opex	Operational expenditure
PBP	Payback period
PDCA	Plan-Do-Check-Act
PFC	Perfluorocarbon
ROI	Return on Investment
SAR	Second Assessment Report
SPI	Sustainable Process Index
TCO	Total Cost of Ownership
TEEB	The Economics of Ecosystems and Biodiversity
UBA	German Environmental Protection Agency
UBS	Underbody sealant
UK	United Kingdom
USEPA	US Environmental Protection Agency
UVA	Utility Value Analysis
VDI	Association of German Engineers
VOC	Volatile Organic Compound

1. Introduction

Environmental management systems have experienced increased importance within companies to address public and legal environmental concerns. The aim of environmental management systems is to ensure legal compliance on the one hand and continuous improvement of environmental performance on the other hand (Förtsch and Meinholz, 2014). Due to its cross-sectional character, environmental management affects all parts of the organization. Besides managing environmental performance of existing business operations, environmental management systems also focus on business planning processes (Burschel, 2004).

Another cross-sectional system is the management accounting system. In contrast to financial accounting, which is concerned with external reporting of ex-post financial performance, management accounting intends to support ex-ante internal management decision-making processes. These decision-making processes comprise amongst others cost-benefit analyses, budgeting processes, cost allocation processes or investment appraisals. Hence, the management accounting system is also referred to as the internal accounting system. (Zimmermann, 2011)

The overlapping part of both systems deals with environmental issues in business planning processes. When building a new plant or replacing equipment, costs and benefits need to be forecasted to support the upcoming investment decision. In addition, these decisions have an impact on the environmental performance as well. This overlap of environmental information in form of physical flows with monetary information is referred to as environmental management accounting (IFAC, 2005).

However, the field of environmental management accounting is still young and environmental management accounting methods are currently under development (Faßbender-Wynands *et al.*, 2009), leading to the subsequent problem situation of this thesis.

1.1. Problem situation

The strategic goals of a company are typically expressed in quantitative financial values (Hungenberg, 2012). Hence, target values in form of financial ratios or figures are formulated on company level and broken down to its organisational units. For instance, the targeted percentage of return on investment (ROI) is determined at ten percent as strategic goal. In this case, this strategic goal is broken down to the business units of a company. Therefore, the expected returns of competing investment objects are calculated and investment objects with a ROI below the targeted ten percent are excluded from further consideration. With this procedure, management accounting professionals ensure that investment decisions support achieving the targeted strategic financial goal.

Besides financial goals, companies increasingly start formulating strategic environmental goals (Burschel, 2004). Nonetheless, challenge remains regarding the achievement of these environmental goals (Liesen *et al.*, 2013). This challenge originates from two sources, which is on the one hand the formulation of the environmental goals and on the other hand the management accounting system missing to support the achievement of these environmental goals.

Environmental goals are regularly expressed in a qualitative way. Nevertheless, to enable monitoring the achievement of strategic environmental objectives, the associated accounting ratios need to reflect the values of the strategic goals (Gladen, 2011). Hence, environmental goals need to be expressed in quantitative values. Due to the qualitative expression of environmental goals, possible conflicts with quantitative financial goals remain intangible. This conflict mainly comprises the incomparability between qualitative and quantitative strategic goals. With the establishment of quantitative environmental goals, this subtle conflict turns tangible especially with environmental management measures that do not provide any profitability (Dyckhoff and Souren, 2008). As a consequence, the decision-maker becomes aware of the environmental impacts besides the already-known financial impacts in order to come to a comprehensive investment decision.

In addition, companies need a systematic integration of indicators or ratios in the decision-making processes that is analogous to achieving financial goals. Therefore, it is necessary to link physical environmental information with the underlying monetary information of investment decisions . This physical environmental information is tracked by the environmental management system. Hence, the environmental accounting system as overlapping system intends to provide such a comprehensive data base.

However, the systematic integration of environmental management information in management accounting processes such as investment appraisals remains a research gap (Herzig and Schaltegger, 2009). While academic literature discusses possible integrated environmental investment appraisal methods, none of these methods has established as accepted standard so far.

1.2. Research objective

Basing on the identified research gap in the previous subchapter, the first step of this thesis intends to assess methods dealing with the integration of environmental impacts in investment processes. This step further aims to perform a deficit analysis to identify reasons which have prevented these methods to establish as accepted standard in business. The concluding step reveals the development of a method based on the insights of the deficit analysis.

Hence, the research objective of this thesis is to develop a method to systematically integrate environmental impacts in investment decisions within companies (integrated investing method) and to verify its practical applicability. With the help of such an integrated investment decision, companies should be able to execute environmental management accounting to consequently achieve strategic environmental and financial goals. Therefore, the main research question is formulated as follows:

Main research question:
How to integrate financial and environmental data in investment processes to achieve strategic environmental and financial goals of companies?

1.3. Methodology

The methodology describes the way to solve the problem situation by achieving the research objective. However, to answer this research question, it is necessary to develop an integrated method that offers a sufficient degree of scientific quality on the one hand and is able to be applied in business practice on the other hand. Hence, the integrated investing method needs to meet requirements corresponding to theory and practice.

Regarding the theoretical development of the integrated investing method, the requirements originate from the outcome of the deficit analysis of existing methods. Additional requirements emerging from method development, as discussed in current academic literature, aim to ensure a sufficient degree of scientific quality. In conclusion, the first sub-research question is formulated as follows:

Sub-research question 1:
Which requirements does the integrated investing method need to meet in order to ensure a sufficient degree of scientific quality?

Besides requirements ensuring scientific quality, the other aim is to ensure successful practical application of the integrated investing method. In this context, current academic literature on method development reveals a set of additional requirements which the method needs to meet. Therefore, the second sub-research question is formulated as follows:

Sub-research question 2:
Which requirements does the integrated investing method need to meet in order to ensure its practical applicability?

After conducting the deficit analysis of currently existing methods and composing a set of requirements ensuring sufficient scientific quality and practical applicability, the concluding step comprises the method development. As already indicated in the introductory passage, the integrated method can be categorised in the field of environmental management accounting, which overlaps with management accounting and environmental management systems. Both systems provide methods that have already established as common accepted standard. Therefore, it is necessary to assess methods that might be able to serve as a basis of the concluding method development. To provide a suitable framework for this assessment, the previously developed set of requirements provides the basis of this method screening and evaluation. Hence, the third sub-research question is formulated as follows:

Sub-research question 3:
How well do additional methods from environmental management and management accounting systems meet the requirements to qualify as a basis for the development of the integrated investing method?

Besides the compliance with requirements ensuring scientific quality, the integrated investing method also needs to be applied in a real life business context to verify its successful applicability in practice. Furthermore, the method application intends to verify whether the integrated investing method is able to support the strategic environmental goals of an existing company. Hence, the fourth sub-research question is formulated as follows:

Sub-research question 4:
Does the method application verify the practical applicability of the developed method and the ability to manage and control strategic environmental goals of an existing company?

Structure of this dissertation

To describe the current state of academic knowledge and business practice, it is necessary to deal with the main object of this thesis which is the investment process. Hence, the second chapter comprises an introduction into the investment process within companies as well as the most common conventional investment appraisal methods. The second part of this chapter discusses current methods aiming to integrate environmental impacts in investment decisions. The discussion intends to identify reasons for their immaturity in practical application with the help of a deficit analysis.

Based on the results of the deficit analysis and current academic literature on method development, a set of requirements, ensuring sufficient scientific quality on the one hand and practical applicability on the other hand, is intended to be developed in the third chapter. Thus, the first two sub-research questions are answered within the first part of the third chapter. Moreover, the third chapter aims to identify and evaluate additional methods which might serve as a basis for the development of the new integrated investing method. The result of the evaluation of the identified methods according to the requirements provides the answer to the third sub-research question. The final part of the third chapter intends to comprise the development of the new integrated investing method.

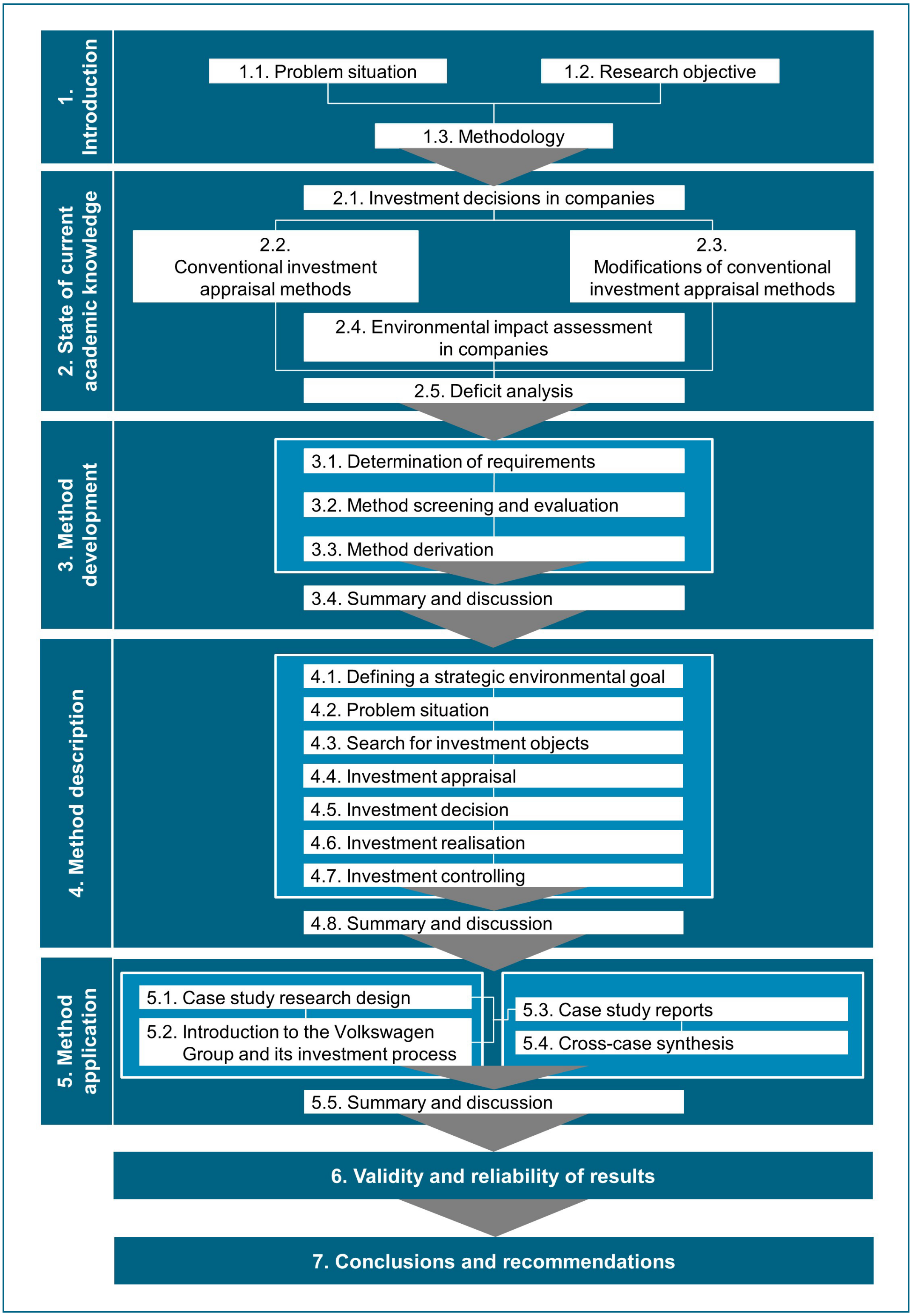
The result of the method development process is described in the fourth chapter containing the description of the new integrated investing method. This method description is structured along the previously identified main object of this dissertation in form of the investment process in companies.

After having developed the new integrated investing method, the fifth chapter intends to apply the method in real life business context in order to provide an answer to sub-research question four. Moreover, this method application chapter intends to verify the method's practical applicability on the one hand and its ability to manage and control environmental goals of an existing company on the other hand.

Finally, the validity and reliability of the results are discussed in chapter six to finally provide the conclusion and recommendations for further research within the subsequent chapter. Within this last chapter, the main research question of this thesis is going to be answered as well.

The methodological structure of this dissertation is also illustrated in Figure 1.

Figure 1: Methodological structure of this dissertation



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2. State of current academic knowledge

2. State of current academic knowledge

This chapter represents an introduction to the current academic knowledge of the corresponding issues of this thesis. While the first subchapter highlights the investment process within companies, the second subchapter discusses conventional investment appraisal methods which are commonly used in business practice. The following subchapter analyses environmental modifications of the previously identified investment appraisal methods. Finally, before the final deficit analysis summarises the weaknesses of the discussed methods, the current academic knowledge regarding environmental impact assessments in companies is introduced.

2.1. Investment decisions in companies

2.1.1. Attributes and characteristics of investments in literature

Purpose of investments

According to Poggensee (2011), investment decisions are a critical factor for the success of a company since the invested capital is bound for long time. This in turn restricts the scope of action of a company. Hence, it is important to invest into projects that support the company's strategy so that strategic goals can be achieved. Therefore, investment decisions describe the direction of the future development of a company (Jasch and Schnitzer, 2002) and thus need to be taken with the intention to support strategic goals of a company.

Hence, the origin of the necessity for investments can be found in the formulation of strategic goals. These goals are typically formulated as financial values such as a targeted return on investment or a targeted net present value which should be added to the company value (Hungenberg, 2012). However, also qualitative goals are formulated such as a top position in an external ranking or a defined amount of patent applications (Gladen, 2011).

Strategy implementation describes the way to achieve these goals. Hence, the task of the product management is to achieve these goals with either existing products or by developing, marketing and selling new products. The underlying strategic marketing decisions are either based on a previous outside-in or inside-out analysis. While the inside-out analysis focuses on the question which products can be developed and sold on which markets with existing resources, the outside-in analysis works with the opposite perspective. Hence, the outside-in perspective starts with an analysis of the target market to derive a product idea to finally identify the internal resources necessary to produce and sell this product (Grünig and Kühn, 2011).

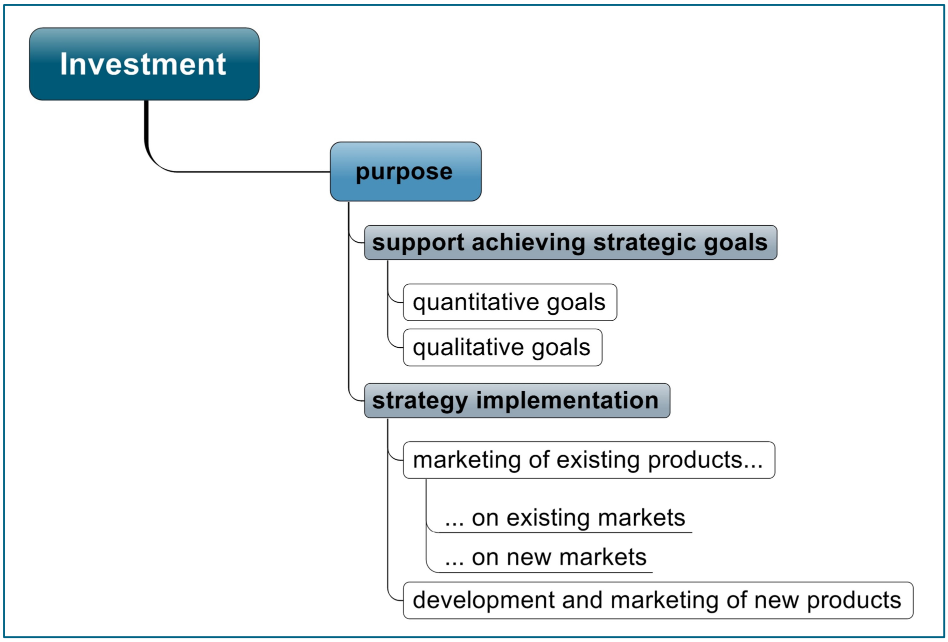
In conclusion, before the investment planning process is started within a company, strategic goals need to be determined and decisions regarding new product development or marketing measures of existing products need to be made. These decisions, in turn, impact on the production facilities of a company. Hence, new plants need to be established or existing plants are extended or adjusted.

The extent to which these measures are examined is limited by the capital budgeting process which runs parallel to these strategic decisions. Therefore, the marketing or sales management has to forecast sales and expected turnover which in turn determines the size of capital budgets, cost budgets and targeted profits. (Zimmerman, 2011)

The subsequent operational strategy implementation begins with comprising amongst others the investment planning process. This process serves to support the strategic goal by identifying the most efficient way of investing. (Grünig and Kühn, 2011)

The following figure provides an overview over the different purposes of investments in companies:

Figure 2: Characteristics of the investment attribute 'purpose'



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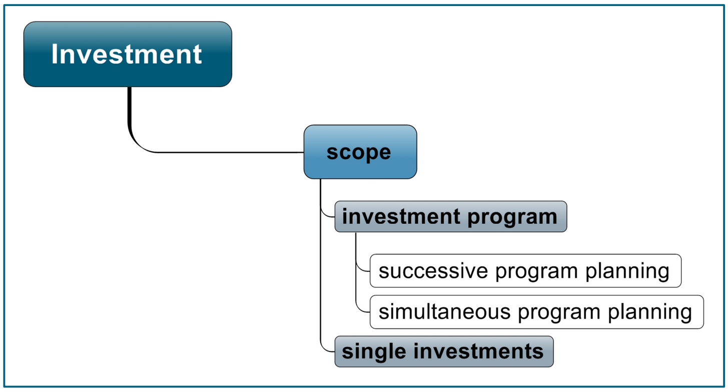
Scope of investments

Regarding the scope of investments, the differentiation between single investments and investment programs is vital for the investment process. As described above, the strategic goals of a company influence the investment planning process. In case the achievement of strategic goals requires investing in several mutually non-exclusive investment objects, the assessment of the best combination of these objects is referred to as investment program planning (Becker, 2012).

The scenario in which another department (e.g. sales, marketing, product management, etc.) determines the size of capital budgets is referred to as 'successive investment program planning'. In contrast to that, the interdependencies and given limitations are recognised and sorted out in close cooperation between both departments with simultaneous programming. (ibid.) The following figure provides an overview of the different scopes of investments in companies:

Figure 3: Characteristics of the investment attribute 'scope'



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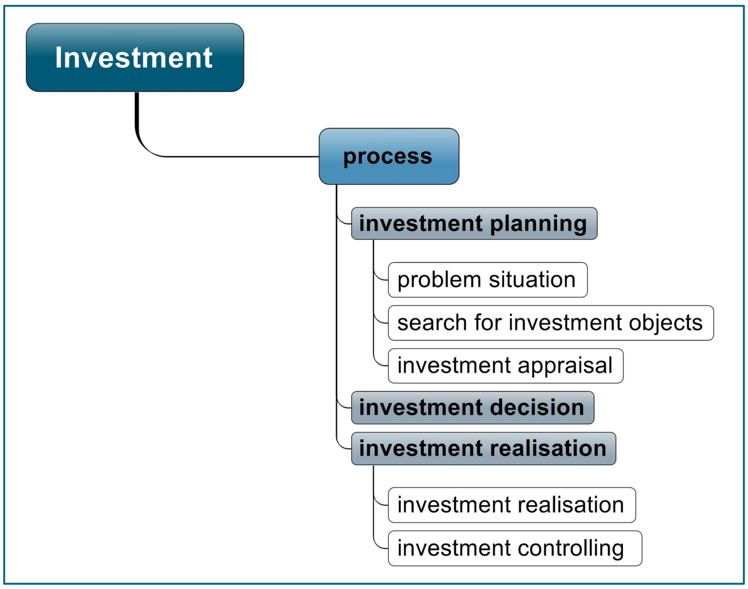
Process of investments

The investment processes for single investments contains six steps which are iteratively run through. First, the problem situation is formulated pointing towards an investment need. The second phase is characterised by research for investment objects which might be able to solve the previously-described problem situation. The next step comprises the appraisal of competing investment objects. In this phase, the profitability of each investment object is projected and compared to the other investment objects. While the fourth phase is defined by the actual investment decision, the investment object is realised in phase five. Finally, the last phase deals with the ex-post analysis of the originally projected profitability with the actual profitability of the investment object. (Poggensee, 2011; Prätsch *et al.*, 2012) The following figure provides an overview over the different process steps of investments in companies:

Figure 4: Characteristics of the investment attribute 'process'



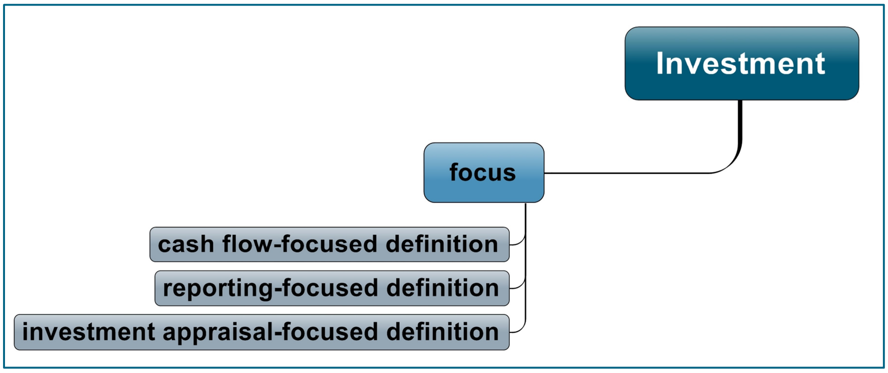
Source: Own illustration based on sources above

Focus of investments

Prätsch *et al.* (2012) differentiate between two perspectives when defining investments. On the one hand, there is a cash flow-focused investment definition. Thus, investments are defined as cash flows which are characterised by outflows at the beginning of an investment with associated cash inflows at later points of time. On the other hand, there is the reporting-focused investment definition which concentrates on the financial localisation of investments within the company's balance sheet.

Poggensee (2011) also constitutes a lack of consistency in defining investments. He identifies three popular perspectives from which to define investments. One perspective corresponds with Prätsch *et al.* (2012) in recognising the timing of cash flows as central point of the definition. The second perspective deals with the intention of the investment which is to acquire fixed (tangible or intangible) assets. The third perspective concentrates on the investment appraisal itself and its intention to create a basis of comparison to alternative investment objects. (Poggensee, 2011) The following figure provides an overview of the different focuses of investments in companies:

Figure 5: Characteristics of the investment attribute 'focus'



Source: Own illustration based on sources above

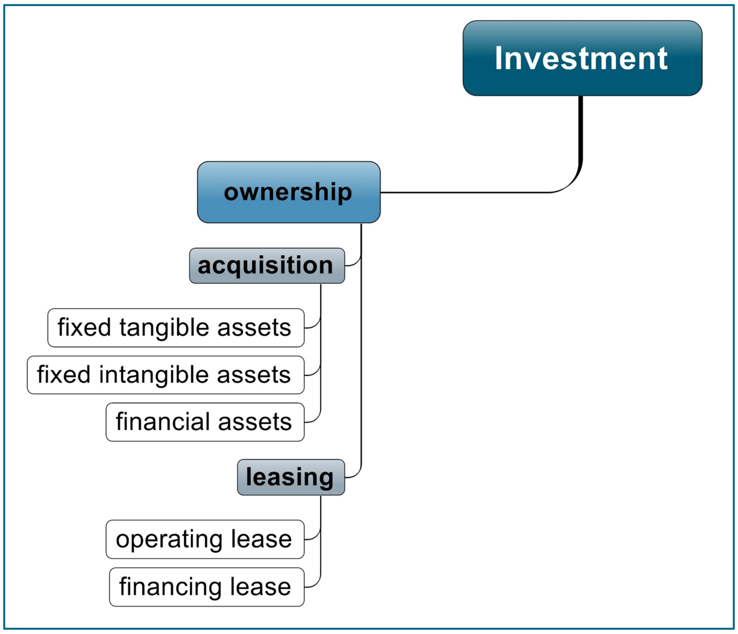
Ownership of investments

Besides these capital asset-oriented investment definitions, Pape (2011) adds a financial perspective. Hence, investments can also comprise the merger or acquisition of external companies but also the acquisition of financial entities generating profit such as financial derivatives, loans, bonds or securities.

While literature on investments usually assumes the acquisition of an asset, leased assets are also part of this discussion. McLaney (2009) differentiates between operating and finance leases. While operating leases comprise hiring an asset instead of purchasing it, finance leases occur in form of sale and leaseback contracts, in which the user purchases the asset at first place, sales it to a financier in a second step to finally lease it back in order to continue its utilisation. (ibid.) Although the actual ownership is transferred to a third party (financier), the control and operation remains at the user.

The following figure provides an overview over the different ownership options of investments in companies:

Figure 6: Characteristics of the investment attribute 'ownership'



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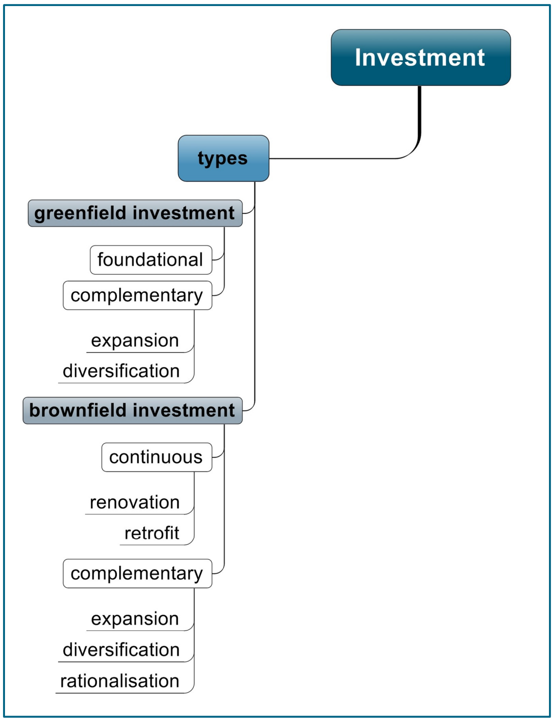
Types of investments

In addition to various definitions of investments, the literature describes three main categories regarding the type of investments. The first category refers to foundational investments to acquire the first property plant and equipment allowing a start-up business to set up its operations. The second category comprises continuous investments for existing plants and equipment, for instance investments preserving production capacity such as renovation or retrofitting of existing plants and equipment. The third category is characterised by complementary investments. On the one hand, this can involve expansion of production capacity by acquiring additional plants or equipment. On the other hand the efficiency of already existing machinery can be increased by rationalisation investments. In addition, this third category also comprises diversification investments necessary, for instance, to meet the trend of mass customisation, for instance. (Prätsch *et al.*, 2012)

Apart from these three main types of investments, the literature highlights two additional terms which roughly summarise the variety of investment categories. On the one hand, there is the term of 'greenfield investments' which described the establishment of new facilities from scratch. These new facilities can either serve as foundational investment or as complementary (e.g. for expansion or diversification) investment. On the other hand, there is the term of 'brownfield investment' which involves the acquisition of existing facilities. This might be the case for continuous investments or complementary (e.g. rationalisation) investments. (Morschett *et al.*, 2010)

The following figure provides an overview of the different types of investments in companies:

Figure 7: Characteristics of the investment attribute 'types'



Source: Own illustration based on sources above

Time period of investments

Another important issue regarding relevant specifications is the time period under consideration. The concept of life cycle costs (LCC) sums up all costs associated with an asset along its complete life cycle. Since the term 'life cycle' is used by several academic professions, it is important to differentiate between the environmental and economic definition of life cycle. Both professions refer to the term 'life cycle' when considering more than just the production and utilisation of a product. However, the biggest difference concerns the focus of the phases before and after production and utilisation.

While the economic life cycle ranges from research and development of the product, over production to marketing (i.e. utilisation of the product from a company's perspective) and finally removal from the market, the ecological life cycle ranges from resource extraction to production and utilisation of the product to finally end with its disposal.

With regard to the activities prior to production, the environmental life cycle perspective considers all activities necessary to extract and process the resources needed to manufacture the product. In contrast to that, the economic life cycle perspective considers research and development activities as relevant step prior to production. Also the phases after the production and utilisation differentiate between both perspectives. While the economic perspective assumes the end of manufacturing and marketing activities of the product, the environmental perspective focuses on the disposal of the product and its impact on the environment.

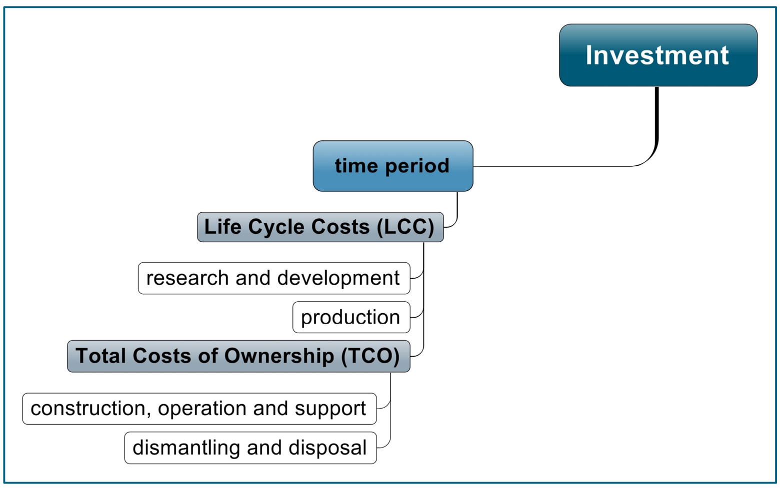
According to Schebek (in Ausberg *et al.*, 2015), both perspectives influence each other. In order to generate an environmental impact in form of resource extraction, a product first needs to be developed. During production and utilisation, the product consumes resources and causes emissions impacting on the environment. Finally, when it is not economically viable to manufacture and market the product, the impact decreases. However, at the end of the functional life cycles of the products, the disposal causes additional impacts on the environment. Hence, environmental impacts are connected to market mechanisms such as economic life cycles. (ibid.)

When discussing the concept of LCC, the economic perspective of the life cycle is assumed as underlying basis. Ideally, the costs of an asset are recorded in the different phases which are structured into research and development, production and construction, operation and support as well as dismantling and disposal of an asset (Lichtenvord *et al.*, 2008). While conventional economic concepts of LCC focus on all associated direct and indirect costs, environmental LCC studies complement these data with corresponding external costs (i.e. environmental impacts from resource consumption and emissions) which should be internalised to represent all relevant costs (ibid.).

Nevertheless, the existence of various actors involved in the life cycle of an asset creates the problem of who should bare which costs. Especially, since the costs of one actor might be the revenues of another actor. Therefore, the term of total cost of ownership (TCO) narrows down the scope and time period of recorded costs. As Thiede *et al.* (2012:275) claim: "*TCO subsumes all cost proportions that occur for the operator of a machine*". Examples for these subsumed costs may involve "*acquisition, installation, training, energy, maintenance, planned or unplanned downtime and disposal*" (ibid.:276). Additional costs under consideration might involve costs of capital and depreciation.

The following figure provides an overview over the periods of time under consideration of investments in companies:

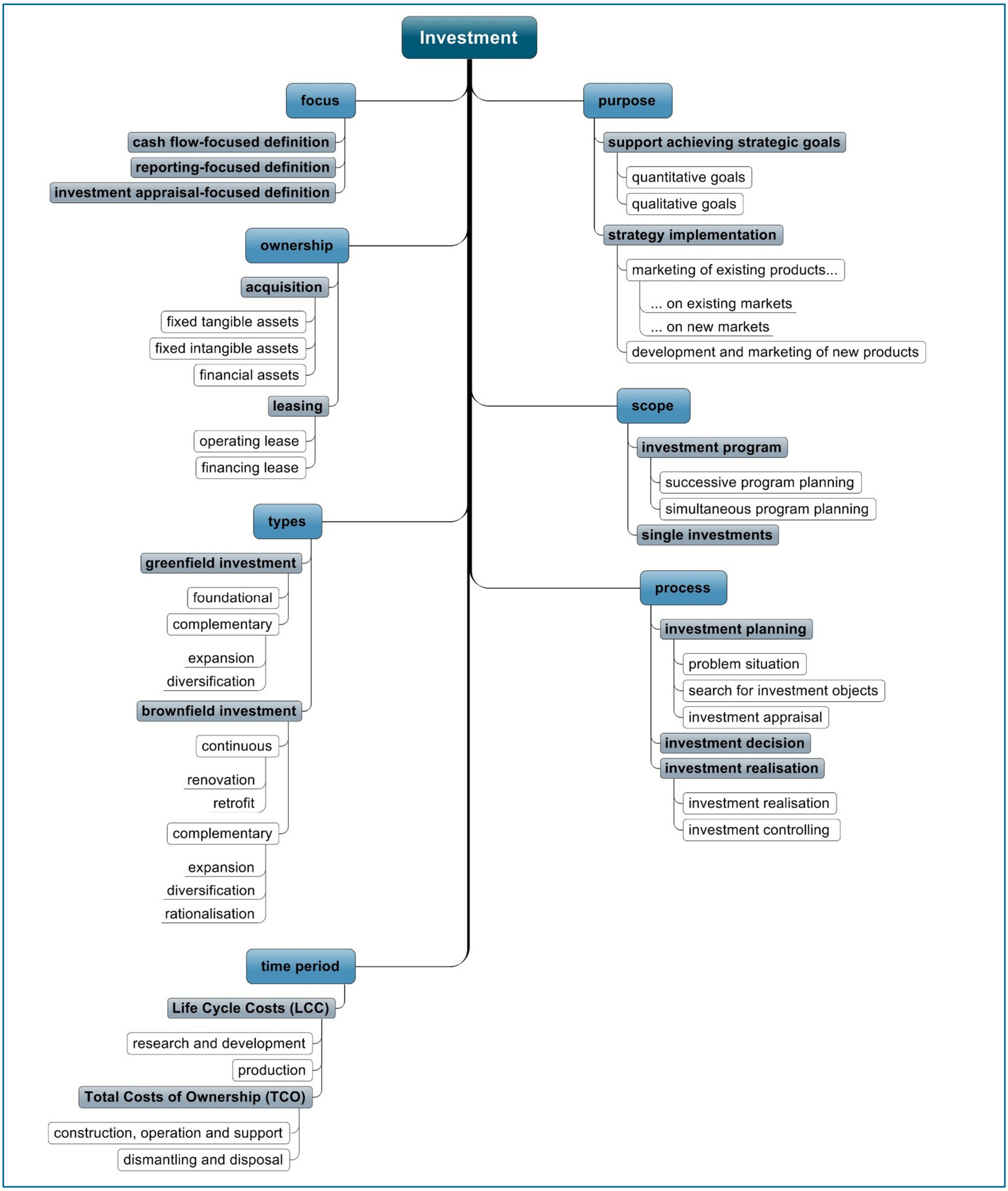
Figure 8: Characteristics of the investment attribute 'time period'



Source: Own illustration based on sources above

The various attributes and their corresponding characteristics which are discussed in the literature addressing investments are summarised in the following figure:

Figure 9: Overview of attributes of investments as described in literature



Source: Own illustration based on sources above

2.1.2. Attributes and characteristics of investments in context of this thesis

Since there is a huge variety of characteristics and no consistent definition of investments, it is necessary to determine the attributes and characteristics of investments for the context of this thesis.

Regarding the *purposes* of investments, this thesis focuses on the aim to support the achievement of strategic goals of a company, since the alternative strategy implementation does not necessarily involve investment decisions. In addition, the investment appraisals in today's business practice are expressed along the quantified strategic goals of a company. Hence, decision-makers aim to support strategic goals of a company with their investment decisions.

The *scopes* of investments differentiate between investment programs and single investments. Since the sum of single investments form an investment program, the scope focuses on assessing single investments in context of this thesis.

Regarding the *processes*, this thesis discusses the implications of the complete investment process, ranging from investment planning, over its decision to the investment realisation. This decision is taken based on the various opportunities the complete process offers for the integrated investing method to adjust and extend existing investment practice in companies.

Concerning the *focuses*, the cash flow-based definition is considered as result of systematic exclusion. While the investment appraisal-based definition highlights only one phase of the investment process, the reporting-based definition is concerned about the localisation of investments in the balance sheet. This localisation, however, does not offer enough level of detail since it sums up each investment value in one aggregated figure at only one point of time within a balance sheet.

The *ownership* attribute differentiates between acquisition and leasing fixed assets. Due to the cash flow-based definition of investments, which recognise an initial cash outflow at the beginning of ownership of the fixed tangible-assets, leasing is not considered to be part of this thesis. In addition, the literature discusses leasing options as part of corporate financing which is also not covered by this thesis. Since the acquisition of intangible assets and financial assets do not necessarily involve an environmental impact, the acquisition of fixed tangible assets is part of the characteristics in context of this thesis.

Furthermore, the literature differentiates between several *types* such as greenfield and brownfield investments. The existence of environmental impacts is the reason behind the choice of investment types. As a consequence, greenfield investments as well as brownfield investments are considered within further research and discussion.

With regard to the *time period* under consideration, the ownership of the fixed tangible asset is considered from the operator's view, which includes the phases described within the TCO-approach (i.e. construction, operation and support as well as dismantling and disposal).

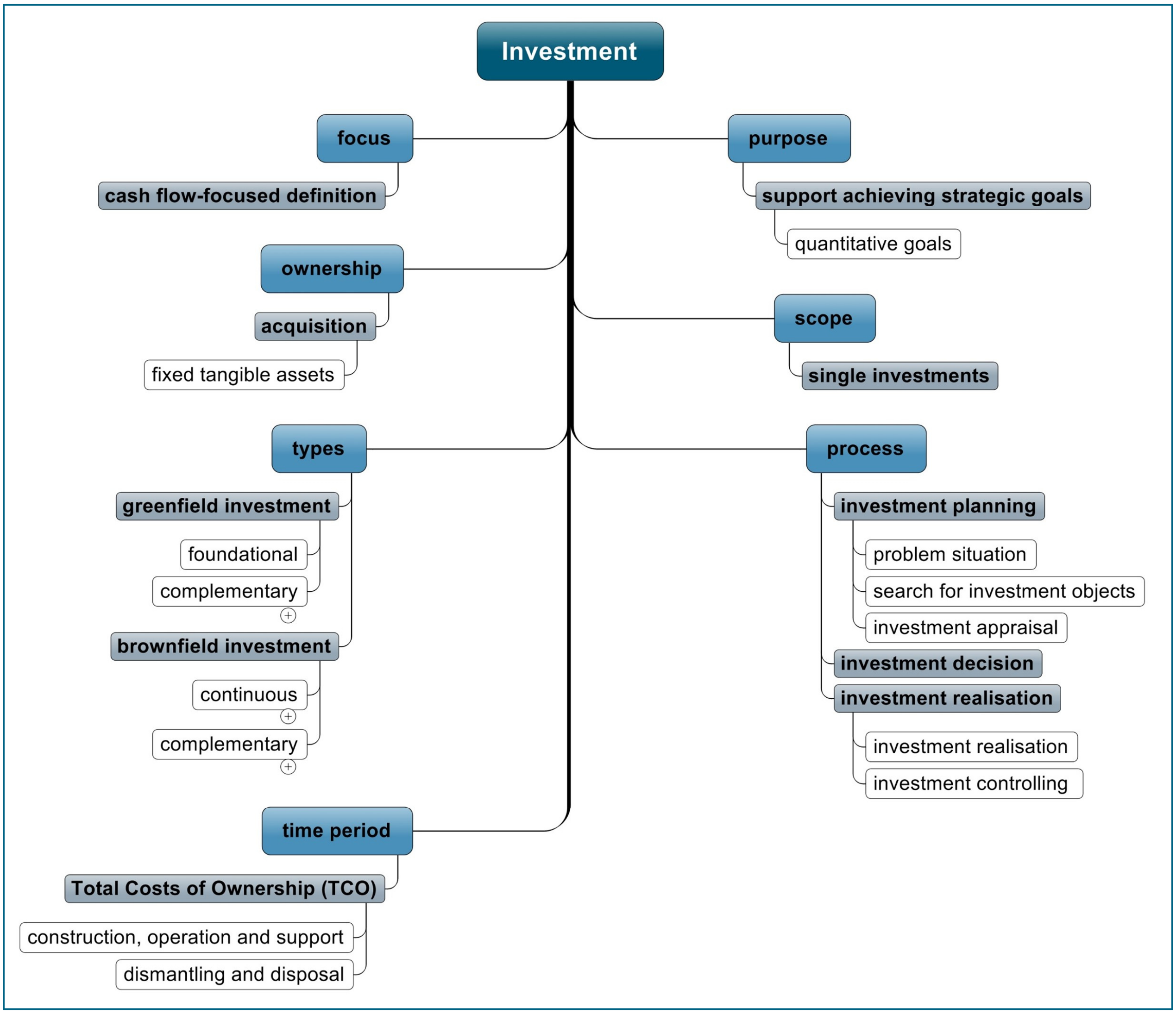
Definition of investments in context of this thesis

Investments are defined as single investments in form of cash outflows enabling to acquire fixed tangible assets for greenfield or brownfield sites, which generate (imputed) cash inflows over the time of the operator's ownership, aiming to eventually help a company in achieving its strategic goals.

Hence, cash outflows in form of direct and indirect costs (and also imputed cash inflows in form of avoided costs) are considered as long as the investment object is owned and controlled by the company.

The following figure summarises the definition of investments used in context of this thesis.

Figure 9: Attributes and characteristics of investments in context of this thesis



Source: Own illustration based on sources above

2.2. Conventional investment appraisal methods

Investment decision vs. investment appraisal

The literature often suggests that the result of the investment appraisal already implies the investment decision. However, Prätsch *et al.* (2012) argue for a strict separation between investment appraisal and investment decision as the people involved within these two phases are separate persons. While management accounting professionals are responsible for the calculation of the investment appraisal, the executive management is responsible for making the investment decision (ibid.).

Poggensee (2011) also argues for a strict separation since investment appraisal methods work with simplified models trying to express reality in quantitative values. This representation of reality involves a reduction of complexity with the help of assumptions. Nevertheless, the decision-maker has to consider also non-monetary and qualitative criteria to make a comprehensive investment decision.

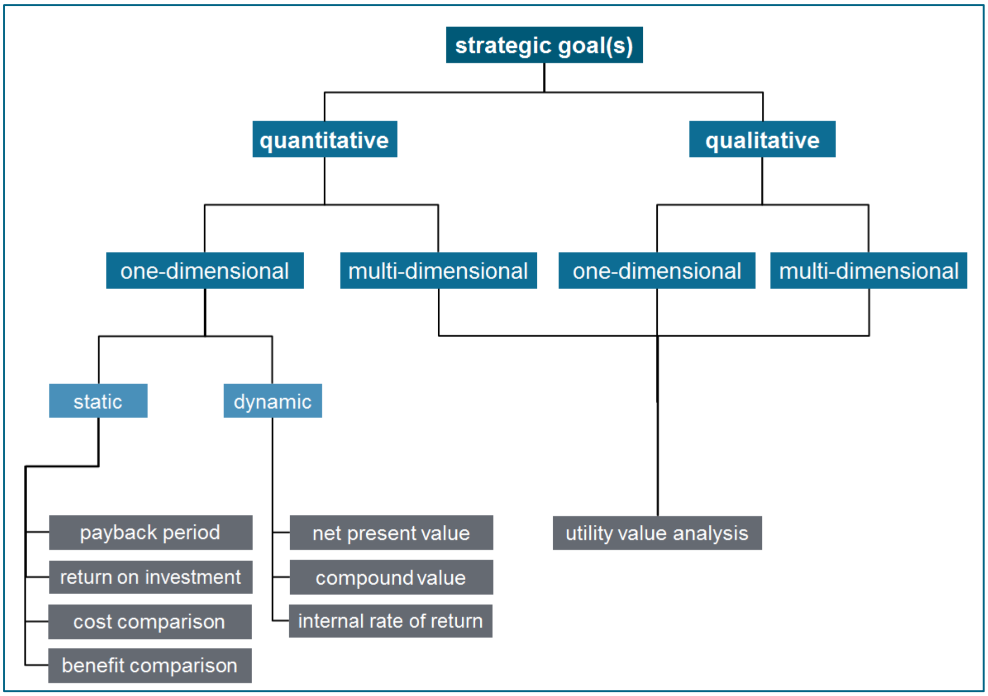
Another argument can be seen in the different objectives of the two phases. On the one hand, the investment appraisal intends to create a quantitative value for each investment object. The quantitative values of the competing investment objects can be compared to each other to determine their relative advantageousness. On the other hand, the investment decision aims for an improvement of the current state of the company. This improvement is achieved by adding value to the company value through the returns or saved operating expenses caused by the investment object. Hence, investments aim to enable the company in achieving its strategic goals. (ibid.)

Classification of investment appraisal methods

The classification of investment appraisal methods depends on the formulation of strategic goals which the methods intend to support. Hence, the first step is to distinguish between quantitative and qualitative strategic goals. Furthermore, the second step is to clarify whether investment appraisal methods have to support one strategic goal or whether there are several goals that have to be achieved equally. The third step comprises a differentiation between single independent investments and an investment program in which several investments depend on each other. (Poggensee, 2011)

Figure 10 provides an overview of the classification of strategic goals and the corresponding investment appraisal methods.

Figure 10: Classification of strategic goals and corresponding investment appraisal methods



Source: According to Poggensee, 2011

While static investment appraisal methods mostly concentrate on the profitability and payback period of an investment, dynamic investment appraisals recognise the points of time of cash inflows and outflows. Hence, dynamic investment appraisal methods include interest rates to calculate the net present value of an investment or the internal rate of return. Dynamic investment appraisal methods are perceived as superior to static investment appraisal methods since the recognition of the time value of money enables the calculation to produce more realistic results. (Jasch and Schnitzer, 2002)

Although static investment appraisal methods do not qualify as the only basis of investment decisions, since they lack recognising the time value of money, they are still commonly used in companies (Poggensee, 2011). One reason for this contradiction can be seen in the simple calculation enabling a quick application and rough orientation. Hence, the most common static investment appraisal methods (i.e. return on investment, payback period, cost or benefit comparison) are discussed in this thesis as well.

Risk and uncertainty in investment appraisal methods

Other important aspects when discussing investment appraisal methods are the issues of risk and uncertainty. While risk is commonly stated as the damage impact multiplied by the probability of occurrence of a negative event, uncertainty deals with the lack of knowledge about the consequences of the investment as well as uncertainty about the data quality level. (Poggensee, 2011)

However, risk management and also uncertainty originating from a low level of data quality are not in the focus of this thesis. Hence, the premise is given that the person calculating the investment appraisal retrieves data and also considers relevant risks in all conscience according to the general prudence principle in accounting.

According to a survey of Truong *et al.* (2008), the investment appraisals net present value, internal rate of return, payback period as well as return on investment are the most popular and thus most used among companies worldwide. Hence, the following subchapters introduce and discuss these methods in addition to further approaches completing the most-relevant investment appraisal methods in today's practice.

2.2.1. Payback period

The payback period (PBP) is defined as the period of time in which the invested capital is amortised by the cash inflows of the investment object. The result of the payback period calculation can be expressed in days, weeks, months or years. (Prätsch *et al.*, 2012)

On the one hand, the existence of a payback period itself can already be regarded as an indicator of a profitable investment. Nevertheless, when comparing the relative advantageousness of competing investment objects, the investment object with the shortest payback period indicates the best alternative. This time-based view represents a basic risk assessment, as the near future is perceived as less risky than the distant future. In conclusion, investments with short payback periods express a higher chance of amortising the invested capital than investment objects with long payback periods. (Poggensee, 2011) In addition, quick cash inflows can be re-invested earlier than cash flows occurring in distant future, providing a company financial flexibility, especially in uncertain times.

Due to its simple calculation, the payback period enables quick decision-making. However, Poggensee (2011) argues that it cannot serve as single basis for investment decisions as the payback period does not recognise the lifetime of the investment object. Additional difficulties occur when comparing the payback period of several investment objects with different amounts of capital investment.

A simplified example illustrating this problem can be retrieved in Table 1.

Table 1: Simplified example for payback periods of two investment objects

	Investment object A	Investment object B
Investment need	500.000 €	250.000 €
Profit p.a.	250.000 €	250.000 €
Payback period	2 years	1 year
Expected lifetime	10 years	3 years
Accumulated profit	2.000.000 €	500.000 €

Source: Own example

When comparing the investment objects given in Table 1, investment object B shows a better payback period with only one year of amortisation. Hence, the decision-maker would prefer investing in object B, assuming that no additional information is available. However, the expected lifetime of the two investment objects differs widely. Considering the ten years lifetime of investment object A, in contrast to only three years lifetime of investment object B, the decision-maker might invest in object A, since the accumulated profit of investment object A is superior to object B.

2.2.2. Cost comparison and benefit comparison

The two investment appraisal methods comparing costs and benefits are similar to each other, which is the reason for describing them together in this subchapter. As the name already indicates, the focus of the cost comparison method is on the expected costs of the investment objects. Based on these cost projections, the investment objects are compared to each other. Hence, the relative advantageousness can be concluded from the investment object with the lowest amount of costs. Nonetheless, the absolute advantageousness can only be determined in case of replacement or rationalisation investments when comparing the business-as-usual scenario (i.e. opportunity costs of not investing) with the costs of investing into the investment object. (Götze *et al.*, 2008)

The considered expenses comprise operating costs (e.g. for personnel expenses, costs for raw materials, energy, repair and maintenance) as well as financial costs (e.g. depreciation, interest and taxes). The method does not differentiate between fixed and variable costs since all cost accounts of an investment object are accumulated. (Poggensee, 2011)

The cost comparison method bases on the assumption that the revenues and production capacities of the competing investment objects are equal. Since variable costs depend on the planned production capacity, which might be subject to frequent changes, the cost comparison method calculates with the average costs. (Götze *et al.*, 2008) Hence, the cost comparison method ignores the different points of time on which costs and benefits might occur, which therefore classifies as static investment appraisal.

The basic assumptions of similar production capacities and revenue amounts of competing investment objects as well as the ignorance of the time value of money are major points of criticism. Hence, the calculated amounts of costs provide a low likelihood to occur in reality after the investment object has been realised. (Poggensee, 2011)

The benefit comparison method compares the profits of competing investment objects. Hence, the amount of costs as result of the cost comparison method is deducted from the projected revenues of the investment object. Besides this difference, the same assumptions (i.e. identical production capacities and average of variable costs) are applied within the benefit comparison method, concluding the same criticism. (Götze *et al.*, 2008)

With regard to the absolute advantageousness, the investment object should be realised if the profitability is greater than zero. When comparing several investment objects to each other, the relative advantageousness is determined for the investment object with the highest profitability. (ibid.)

2.2.3. Return on Investment

The financial ratio Return on Investment (ROI) determines the profitability of an investment object by calculating the relation of profit and invested capital. The result of the ROI ratio is expressed in a percentage. (Poggensee, 2011)

The ROI ratio is mostly applied on company-level to serve as an indicator of the profitability of the whole company. In this case, the literature refers to the ROI as a profitability ratio pyramid since the nominator and denominator are composed by ratios as well. (Lachnit and Müller, 2012) However, when applied on an investment object, the composition of the ratio is less complex. The ROI, which is also referred to as Accounting Rate of Return (ARR), is determined by the average profit divided by the average invested capital in an investment object (see formula below). While the profit is calculated by the difference between cash inflows and cash outflows over the lifetime of an investment object, the invested capital represents the value necessary to acquire the investment object. (Zimmerman, 2011) Thus, the formula for the ROI can be displayed as follows:

Equation 1: Return on Investment formula for capital investment objects

$$ROI = \frac{Average\ annual\ profit\ from\ the\ investment\ object}{Average\ annual\ invested\ capital\ in\ the\ investment\ object} \times 100\ \%$$

The expression of the ROI as a percentage enables a conclusion about the efficiency of an investment. If ROI > 0%, the result implicates that the investment is amortised, even without knowing the exact point of time when the investment object amortises. Nevertheless, the decision-maker would decide to invest, since the investment is able to add value to the company's capital anyway.

When comparing the ROI of several investment objects the investment object with the highest percentage is regarded as the most advantageous. Nonetheless, if there is a minimum percentage value defined for the ROI in companies (e.g. requiring a higher ROI than the costs of capital or the market-based interest rate), the decision-maker might tend towards underinvestment since investment alternatives might not meet the minimum required return rate, especially in high interest market environments.

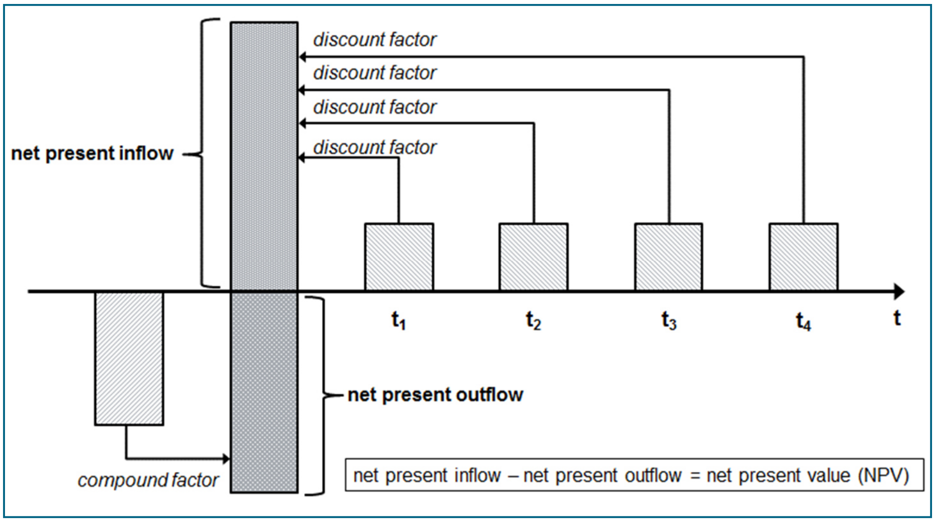
In contrast to the payback period, the ROI is able to consider the lifetime of an investment object. However, the expected profit in the nominator is calculated by averaging the expected cash inflows and cash outflows of the investment object across its lifetime. Hence, the ROI ignores the fact that an investment object's profitability might vary over its lifetime. Just as the payback period, the ROI does not consider the time value of money and thus, is referred to as static investment appraisal method.

2.2.4. Net Present Value and Compound Value

The Net Present Value (NPV) considers the time value of money and therefore classifies as dynamic investment appraisal method. From the date of investment, future expected cash inflows and outflows are discounted or compounded via an interest factor to transfer these cash flows to the same point of time (mostly present time as with the NPV). The discounted cash outflows are subtracted from the cash inflows to calculate the net present value. Hence, the result of the NPV calculation is expressed in absolute monetary value. (Poggensee, 2011)

Figure 11 illustrates the calculation of the NPV:

Figure 11: Illustration of the Net Present Value calculation



Source: Based on Prätsch et al., 2012:347

In case NPV > 0, the decision-maker would decide to invest since the investment object is able to add value to the company. In addition, the investment decision is perceived as less risky since the NPV tries to sketch reality by considering the time value of money in form of the discount factor. Furthermore, the cash flows of the whole lifetime of the investment object are taken into consideration.

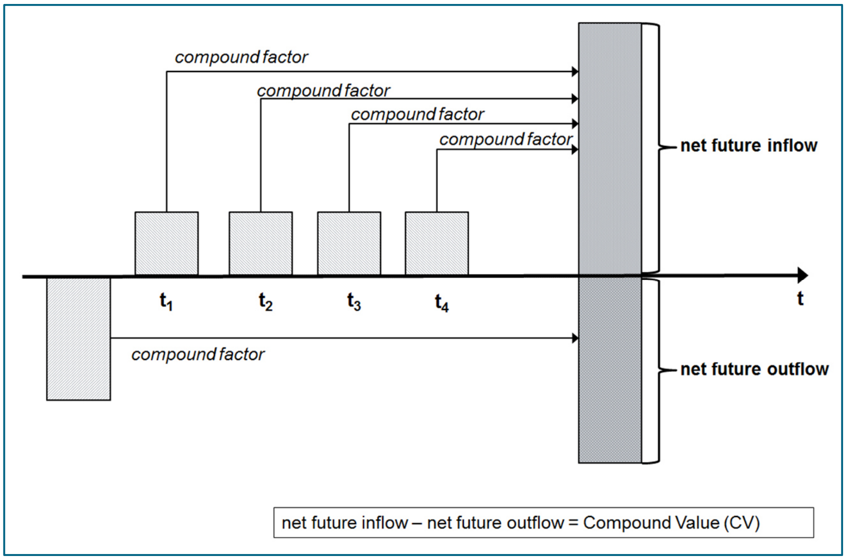
However, the decision-maker might tend to overinvest when deciding to invest in each investment object with a positive NPV. That is why the NPV does not reveal any information about the relation between the investment need and the generated profit such as the ROI. Nevertheless, the decision-maker is able to compare several investment objects with the help of the NPV. In this case, the investment object with the highest NPV is regarded as the most profitable over its lifetime.

The Compound Value method (CV) is similar to the NPV. Both methods are classified as dynamic investment appraisal methods by recognising the time value of money. Nonetheless, the biggest difference between these two methods is the point of time future cash flows are transferred to. While the NPV calculates the added value of future cash flows at the starting point of the investment, the CV focuses on the end point of the investment object’s lifetime. While the NPV therefore makes use of a discount factor, the element transferring cash flows to the end point of the investment object’s lifetime is the compound factor. Nevertheless, both factors base on an interest rate which is mostly based on the weighted average cost of capital or market-based interest rates. (Poggensee, 2011; Götze *et al.*, 2008)

The underlying decision criterion with the CV is the same as with the NPV. Hence, absolute advantageousness is given with an investment object showing a CV > 0 while relative advantageousness is assigned to the investment object with the highest CV.

The following figure illustrates the calculation of the CV:

Figure 12: Illustration of the Compound Value calculation



Source: Based on Prätsch et al., 2012:344

2.2.5. Internal Rate of Return

The internal rate of return (IRR) is the discount factor leading to a NPV of zero. While a discount rate for the NPV calculation is based on general assumptions, the IRR calculates the effective discount rate leading to NPV = 0. Hence, it sets the relation of the investment and the future discounted cash flows and thus, provides an indicator of the efficiency and quality of an investment. In addition, the IRR recognises the time value of money and therefore classifies as dynamic investment appraisal. (McLaney, 2009)

To derive the relative advantageousness of several investment objects, the investment object with the highest IRR is preferred. However, in case of no competing investment objects, the decision-maker would decide to invest if the IRR is higher than the costs of capital or the market-based interest rate. This decision is made on the premise that more value can be added to the company's value by the investment object than with a financial investment on the capital market. (Poggensee, 2011)

The calculation of the IRR is complicated since it is mostly derived by trial-and-error. Furthermore, the IRR leads to unrealistic return rates in some constellations (Zimmerman, 2011). Investment objects with cash flows changing from positive cash flows in one year to negative cash flows in the concluding year even reveal more than one IRR. In this case, it is difficult for the management accounting professional to determine the correct value for the IRR as a basis for decision-making.

2.2.6. Utility Value Analysis

The discussed methods within the previous subchapters can either be classified as a static or a dynamic investment appraisal method and support single quantitative strategic goals. However, in case of multiple quantitative strategic goals or in case of qualitative goals, these investment appraisal methods do not offer a helpful result (compare Figure 10).

Hence, the corresponding investment appraisal methods in these cases must be derived from the group of Multiple Attribute Decision-Making (MADM) methods. The most popular method of this group is the Utility Value Analysis which is therefore in the scope of this thesis (Götze *et al.*, 2008).

The Utility Value Analysis (UVA) intends to calculate a value that consists of a weighted sum of several sub-goals. When conducting the UVA, the first step is to determine the sub-goals under consideration. These sub-goals might comprise various quantitative goals (e.g. NPV, ROI, IRR, etc.), a combination of quantitative and qualitative goals or solely qualitative goals. The second step within the Utility Value Analysis assigns weightings to the sub-goals. Each sub-goal is assigned with a relative importance (step two) so that the sum of all weighted sub-goals is equal to 1 or 100. (Poggensee, 2011; Götze *et al.*, 2008)

Afterwards, the third step comprises a judgement of how far each investment object meets each sub-goal. This judgement can either be conducted on basis of a nominal, ordinal or cardinal scale. These assigned values of the expert judgements are multiplied with the weightings of the sub-goals in the following step (step four) to derive a utility value for each sub-goal. (ibid.)

Finally, the utility values of the sub-goals are added to calculate the overall utility value of each investment object (step five). Hence, unfavourable results of one sub-goal can be compensated by favourable results of other sub-goals unless no minimum value was previously determined functioning as a threshold value. (ibid.)

A generic example of the underlying calculations of a UVA can be retrieved from the following table:

Figure 13: Generic example of Utility Value Analysis

Step 1	Step 2	Step 3		Step 4	
Sub-goals	**Weighting**	**Judgement object 1**	**Judgement object 2**	**Utility Value object 1**	**Utility Value object 2**
Sub-goal A	0.10	1	2	0.10	0.20
Sub-goal B	0.50	5	3	2.50	1.50
Sub-goal Z	0.40	3	5	1.20	2.00
Total	1.00			**3.80**	**3.70**
				Step 5	

Source: Own example

Regarding the investment decision, the absolute advantageousness is given if an investment object is above a targeted utility value. Alternatively, the relative advantageousness is given for the investment object with the highest utility value compared to its competing alternatives. (Götze *et al.*, 2008)

As already indicated the UVA experiences increased popularity within business practice. One reason is the fact that the result in form of a single-score value is easily comprehensible. In addition, the method offers a structured procedure and its underlying simple calculations can be conducted also by non-financial experts. (ibid.)

However, the UVA also faces criticism which mainly focuses on the subjective judgements of the person conducting the method. Besides these judgements, the determination of sub-goals and assignment of weightings to these sub-goals represent subjective steps. The steps of weighting the sub-goals as well as the judgement of the utility values require extensive timely effort. Furthermore, the resulting utility values are accompanied with uncertainty, which is why sensitivity analyses should be conducted to assess the degree of deviation of results, in case assumptions, weightings or judgements change. (Poggensee, 2011)

2.3. Modifications of conventional investment appraisal methods

Before describing the literature on environmental investment appraisal methods, the definition of environmental investments needs to be discussed. Günther (2008) defines environmental investments as all investments providing an ecological relevance. In addition, the author states that environmental investments can either be enforced by legislation or implemented voluntarily. Furthermore, environmental investments might comprise either investments in assets for environmental protection or investments extending, substituting or increasing the efficiency of already existing assets. (ibid.) As a consequence, this broad definition can be applied on the majority of regular investments since there is hardly any asset that does not have an ecological relevance.

Baumast (2009) defines environmental investments as the acquisition of assets for the purpose of protecting the environment. Hence, environmental investment appraisal methods assess the profitability of environment protection investments. In addition, Baumast (2009) refers to the option of the ex-post analysis of environmental investment appraisals to analyse the profitability of past environmental protection investments. On the one hand, this definition narrows down the scope by focusing on assets with the aim of environmental protection rather than all investments with an ecological relevance. On the other hand, this definition concentrates on assessing the profitability of these environmental protection investments. However, the environmental impact of the investment objects is neglected in this definition.

The third definition in this context focuses on the integration of economic and ecological considerations in the investment decisions. Assuming a given strategic environmental goal of a company, Isensee and Michel (2011) state that environmental investments have to contribute to this goal. Hence, the environmental impact of the investment object needs to be quantified and integrated into the calculation of the economic advantageousness. This, in turn, enables the decision-maker to choose the optimal investment object contributing to the environmental and financial goals of the company.

In context of this thesis, the definition of environmental investments is a mixture of the three previously discussed positions. The definition can be separated into two parts. While one part deals with the purpose of the investment object, the other part focuses on the intention of analysis.

With regard to the purpose of the investment object, narrowing down the scope of analysis on assets for environmental protection would represent a too narrow limitation, since other assets also provide a significant environmental impact.

Hence, also investments with the purpose of substituting or extending already existing assets can contribute to minimising the environmental impact and thus should also be regarded as environmental investment.

Concerning the intention of analysis, the definition by Isensee and Michel (2011) represent a comprehensive view by also quantifying the environmental impacts of an investment object. This comprehensive view enables the decision-maker to take an integrated decision representing the contribution to environmental and financial goals of the company. Furthermore, in analogy to the previously discussed financial investment appraisal methods, an ex-post analysis as described by Baumast (2009) is essential to substantiate the financial and environmental effectiveness of investment objects.

Definition of environmental investments in context of this thesis

Hence, the definition of environmental investments for this thesis can be formulated as follows: An environmental investment is the acquisition of a fixed tangible asset that enables a company to contribute to its environmental goals by being able to quantify its environmental impacts to provide the basis of an ex-post analysis.

2.3.1. Ecological Payback Period

As already explained, the financial payback period intends to calculate the amount of time needed to recover the initial capital investment by cash inflows of an investment object. The Ecological Payback Period (EPP) picks up this idea by replacing the cash inflows and outflows with environmental aspects. Hence, the EPP determines the relation of the environmental aspects occurring with the production of the investment object with the annual amount of environmental aspects, which are avoided by operating the investment object (Schaltegger and Sturm, 2000). Therefore, the formula for the EPP can be expressed as follows:

Equation 2: Ecological Payback Period formula for capital investment objects

$$EPP = \frac{env.\,aspects\ caused\ by\ production\ of\ the\ investment\ object}{avoided\ env.\,aspects\ during\ the\ utilisation\ phase\ of\ the\ investment\ object\ p.\,a.}$$

The underlying idea originates from the renewable energy sector where the energy payback "*gives the ratio of net energy produced during the lifetime of the facility, divided by the energy required to build, maintain and supply the facility during all that time.*" (Guerrero-Lemus and Martínez-Duart, 2013:29).

On the one hand, the comprehensive view, including the environmental aspects caused by the production of the investment object, appears to be ecologically useful. On the other hand, however, practitioners are faced with three problems. First, the quantitative data on environmental aspects caused by the production of the investment object are difficult to collect. Second, the EPP is calculated with only one environmental aspect at a time. Hence, it is necessary to find an indicator which is able to represent also other environmental indicators. Third, no environmental impact assessment is conducted which is eventually the aim of this thesis.

2.3.2. Ecological Return on Investment

As described above, the financial ROI determines the profitability of the investment. The calculation divides the average profits generated through the investment object by the capital investment needed to acquire the investment object. Schaltegger and Sturm (2000) suggest a transfer of the ROI to an Ecological Return on Investment (EROI). As with the EPP, financial cash flows are replaced with environmental aspects. Hence, the avoided environmental aspects over the operational lifetime of the investment object are set in relation to the environmental aspects caused over the investment object's life cycle (ibid.). Therefore, the formula can be expressed as follows:

Equation 3: Ecological Return on Investment formula for capital investment objects

$$EROI = \frac{avoided\ env.\ aspects\ over\ the\ lifetime\ of\ the\ investment\ object}{caused\ env. aspects\ over\ the\ life-cycle\ of\ the\ investment\ object}$$

Schaltegger and Sturm (2000) claim that an investment should be regarded as efficient if the outcome is > 1. However, in case of investments not intending to avoid emissions (i.e. investments expanding already existing facilities), the decision-maker should invest in the object which is closest to zero (ibid.).

In contrast to the EPP, the EROI focuses on the life cycle of the project. On the one hand, this comprehensive view satisfies scientific requirements since relevant environmental aspects are not excluded from the analysis. On the other hand, the same criticism applies for the EROI as with the EPP.

2.3.3. Ecological Net Present Value

The financial NPV method classifies as dynamic investment appraisal method since it considers the time value of money. Cash inflows and cash outflows, which occur at different points of time, are discounted or compounded to the same point of time via an interest factor. The discount factor is also in the focus of suggestions regarding an Ecological Net Present Value (ENPV).

Günther (2008) discusses possible adjustment opportunities of the discount factor within the NPV calculation. The premise of the author is that the decision-maker tends to prefer investment objects with cash outflows in the distant future than investment objects with cash outflows in the near future (ibid.). The underlying argument is again the time value of money. One monetary unit in distant future implies less value compared to one monetary unit in near future due to inflation (Götze *et al.*, 2008).

Building on this premise, Günther (2008) discusses transferring this issue on investments and their impacts on the environment. On the one hand, the author claims that expected technical development should lead to an increase of the discount factor since cost savings are expected in distant future. On the other hand, expected stricter threshold values should lead to a decrease of the discount factor, offering the incentive for immediate investment. (ibid.)

The discussion about adjusting the discount factor, with the intention to recognise future environmental impacts, gained popularity with the Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC) published in 1996. The SAR differentiates between a prescriptive discount rate (in literature also referred to as the social or environmental discount rate) and a descriptive discount rate. (Halsnaes *et al.*, 2007)

The descriptive discount rate bases on market-based interest rates. These interest rates are either determined by central banks and are referred to as prime rates or base rates. Another option is the London Interbank Offered Rates (LIBOR), which is defined by the British Bankers' Association and represents the daily average inter-bank interest rate. An alternative to LIBOR is the EURIBOR, which is published by the European Banking Federation and focuses on the average inter-bank interest rate of financial institutions within the European Union. (Becker, 2012)

In contrast to this, the prescriptive discount rate tries to sketch the tendency of humans to prefer paying costs for environmental protection in distant future than paying these costs today. This tendency is also referred to as pure-time preference. (Kula, 2011) Halsnaes *et al.* (2007:136) define the prescriptive discount rate as "*the sum of the rate of pure-time-preference and the rate of increased welfare derived from higher per capita incomes in the future*".

While descriptive discount rates tend towards high rates of four percent or more (especially for risky funds), prescriptive discount rates tend to be the opposite (Halsnaes *et al.*, 2007). In this context, Stern (2007:45) points towards the controversial discussion about environmental discount rates since high discount rates "*favour avoiding costs of reducing emissions now, since the gains from a safer and better climate in the future are a long way off and heavily discounted*".

Shaikh (2012) notes that the debate about discounting environmental impacts overloads the ability of the discount rate since the debate diverges from the original intention of the discount rate, which is the representation of the time value of money. In addition, the debate concentrates on defining an appropriate level for an environmental discount rate and not on the question whether or not discounting is the right tool to achieve inter-generational equity in financial projections. Shaikh (2012) adds that economists generally do not intend to discuss ethical questions within their calculations.

Besides the vast criticism, the government of the UK has determined a discount rate for public long-term projects that declines over the years (see Table 2). While France also prescribes a four percent discount rate for projects below 30 years and a two percent discount rate for projects of over 30 years lifetime, the US government suggests voluntary implementation of declining environmental discount rates. (Halsnaes *et al.*, 2007) However, there is no transparent reasoning behind the determination of these discount rates. In addition, whether or not the level of these discount rates is appropriate with regard to a fair representation of generations of today and the future, is a discussion which is unlikely to end with a globally accepted consensus in the near future.

Table 2: Environmental discount rates as prescribed by the UK Government

Discount rate	Project lifetime
3.5 %	1-30 years
3.0 %	31-75 years
2.5 %	76-125 years
2.0 %	126-200 years
1.5 %	201-300 years
1.0 %	above 300 years

Source: According to Halsnaes et al., 2007

In its discussion about adjusting the discount factor within the NPV calculation, Günther (2008) refers to the inability of the discount factor to appropriately represent inter-generational equity. This argumentation is also shared by Schaltegger and Sturm (2000), who also argue that an adjustment of the discount factor would contradict the inter-generational paradigm as described in the Brundtland report.

2.4. Environmental impact assessment in companies

The problem situation of this thesis highlights amongst others the necessity to express strategic environmental goals in quantitative values to determine environmental impacts of decisions and to enable supporting these strategic goals. However, to determine the environmental impacts of an investment decision, it is necessary to collect, monitor and analyse environmental data in the same quality as corporate financial data is collected, monitored and analysed.

The department coordinating environmental data is the environmental management of a company. The main purpose of environmental management is to ensure a continuous improvement of a company’s environmental performance (Förtsch and Meinholz, 2014). Hence, the organisation along the Plan-Do-Check-Act (PDCA) cycle ensures a standardised way of repetitively defining environmental goals, organisational structures, responsibilities, the execution of programs and audits as well as its documentation (Müller-Christ, 2010).

Successful environmental management necessitates cross-functional collaboration with other departments. In this context, Rathje (2009) assesses the organisational positioning of environmental management departments in companies. Since the author identifies a variety of locations within the organisational structures, Ratje (2009) concludes that the location depends on the overall organisational structure of the company. Nevertheless, since environmental management affects all areas of a company, the hierarchical location of the department plays a minor role when assessing the degree of cross-departmental collaboration regarding environmental management issues. (ibid.)

As the aim of an environmental management system is the continuous improvement of a company's environmental performance, this performance needs to be quantified so that development can be monitored, documented and reported. This process of measuring, monitoring and reporting environmental performance data is referred to as 'environmental management accounting' (IFAC, 2005).

Burschel (2004) notes that the current academic literature has not agreed on a uniform definition of environmental management accounting due to its intense discussion and diverse dissemination in business practice. The author analyses different forms of environmental management accounting systems and differentiates between:

- the connection of environmental management accounting to financial accounting
  - parallel system to financial accounting
  - extension of financial accounting
- the scale of assessment of environmental management accounting
  - focus on physical input and output flows
  - focus on monetary flows
- the scope of assessment of environmental management accounting
  - assessing environmental impacts of products and processes
  - assessing environmental impacts of the whole company (ibid.)

Nevertheless, Baumast (2009) defines environmental management accounting as subsystem of the management accounting business function that extends the classical management accounting tools by ecological components to integrate environment-related issues. Faßbender-Wylands (2009) agrees by referring to the functions of environmental management accounting which match with the functions of a financial management accounting system. Although the author claims that classical management accounting instruments are not originally designed and thus not suited for tracking environmental performance. In addition, the author notes that suitable instruments of environmental management accounting are still under development (ibid.).

Tschandl and Posch (2012) focus on the task of providing information on eco-efficiency and eco-effectiveness as well as identifying opportunities and threats of sustainable development practices. Therefore, environmental management accounting concentrates on physical flows such as waste, water, emissions, energy or other related consumption of resources. (ibid.)

The basis for environmental management accounting is an integrated environmental information system which records all relevant environmental aspects of a company (ibid.). According to an analysis by Isensee and Michel (2011), the most-advanced companies in integrating environmental management accounting still face a lack of additional and detailed environmental data. In most cases, companies are not able to track and monitor data on environmental aspects on equipment level. Resource and emission flows are only available on an aggregated level (i.e. plant or hall level) requiring additional measuring points on equipment level. This fact leads the authors to the conclusion that the development of environmental management accounting is still far from established professional application (ibid.).

Besides the location of measurement equipment of resource and emission flows, an additional issue for the environmental management accounting system concerns the scope of measurement. While the financial management accounting is primary interested in cost-related environmental aspects (e.g. energy or water), the environmental management has to track additional resource and emission flows due to compliance checks with given threshold values.

When exploring the underlying reasons for the lacking detail of environmental performance data, the differentiation between environmental aspects and environmental impacts is vital. According to the ISO (2009:11), an environmental aspect is defined as an "*element of an organization's […] activities or products or services that can interact with the environment*".

Furthermore, the literature differentiates between direct and indirect environmental aspects. Direct environmental aspects are defined as decisions and activities in the context of business operations of the own company. These activities comprise amongst others the development, production, transport and marketing of products. In contrast to that, indirect environmental aspects comprise decisions and activities of suppliers or business partners of a company. (Prammer, 2009)

While this definition of environmental aspects emphasises the interaction between the operations of a company with the environment, the ISO (2009) recommends the establishment of an input-output model as a basis for further quantification and measurement. In this context, the IFAC (2005:30) suggests "*accounting for all energy, water, materials and wastes*" in order to build a so-called "*input-output balance*".

The European Commission (2009:22) provides a more comprehensive list which adds to the following environmental aspects:

- "*legal requirements and permit limits*
- *emissions to air*
- *releases to water […]*
- *use and contamination of land*
- *use of natural resources and raw materials […]*
- *local issues (noise, vibration, odour, dust, visual appearance, etc.), […]*
- *risks of environmental accidents and impacts arising, or likely to arise, as consequences of incidents, accidents and potential emergency situations,*
- *effects on biodiversity.*"

While this list also reveals qualitative environmental aspects, it could even be extended by referring to additional literature. However, the environmental management system focuses on the most relevant environmental aspects. Hence, the European Commission (2009:22) assists in determining the relevance of environmental aspects by defining:

> "*- size, number, frequency and reversibility of the aspect or impact*
> *- existence and requirements of relevant environmental legislation*
> *- importance to the stakeholders and employees of the organisation"*

The step of identifying the most relevant environmental aspects provides the basis of assessing the impacts on the environment. While the definition of environmental aspects concentrates on the interaction of business activities with the environment, the definition of environmental impacts focuses on the consequences of this interaction. Prammer (2009) classifies environmental impacts into three categories:

- change of amounts of natural resources (mostly depletion)
- change of material composition of the natural environment
- change of ecosystems and landscape.

In addition, the author states that environmental impacts can be short-term, mid-term or long-term, reversible or irreversible, constant or of temporary character (ibid.). While environmental aspects can be quantified with the help of measurement technology, quantifying environmental impacts is difficult. The lacking knowledge of cause-and-effect of environmental aspects leads to the necessity of assumptions which are hard to determine in an objective and plausible manner. (Tschandl, 2012; Loew *et al.*, 2003)

Furthermore, the environmental impacts under consideration depend on the scope of assessment. Original Equipment Manufacturers (OEM) of the automotive industry, for instance, face responsibility for the environmental impacts of their products occurring from materials used, air emissions, noise and fuel consumption. With regard to the production, environmental impacts occur from emissions into the air or surface waters, consumption of materials, energy or freshwater, noise emissions, waste, land contamination and many more. (Gruden, 2008) With other industries or products under consideration, this set of environmental impacts would vary significantly.

Because of this variety of environmental impacts, the literature discusses several methods assessing and aggregating environmental impacts in indicators or ratios with the aim of measuring and monitoring the environmental performance of a company (Dyckhoff and Souren, 2008). The aim of these methods is to aggregate environmental impacts to function as a basis for decision-making. Therefore, environmental indicators or ratios should be able to compare alternatives or represent the environmental impacts on different levels (i.e. local, regional, national or international level). (Tschandl, 2012)

Yet, the immaturity of most of the environmental indicators is a restricting factor for application in business practice (ibid.). Pöder (2006:141) recognises "*significant difficulties in adequate and reproducible assessment of their [companies] environmental aspects*". As a consequence, the author observes two kinds of companies. On the one hand, most companies apply intuitive expert judgements, while on the other hand companies tend to install complex and formal assessment schemes (ibid.). In this context, Lion *et al.* (2013) complains about an increasing complexity of environmental impact assessment tools which result in a lack of understanding at business practitioners.

Besides the lack of comprehension of environmental impact assessment methods at business professionals, a survey of large German companies conducted by Schaltegger *et al.* (2011a) reveals another problem. The survey results reveal that only 9.7 percent of the companies apply an environmental accounting. Furthermore, the authors point towards a low involvement of finance and accounting department in sustainability management which is why "*a stronger involvement of finance, accounting and management control is highly recommended*" (Schaltegger *et al.*, 2011b:144).

These results highlight the necessity of increased collaboration between management accounting professionals and environmental management professionals. Dyckhoff and Souren (2008) claim that the degree of collaboration of both professions depends on their ability to accept mutual agreement. However, in case the environmental management professional strictly keeps the focus on improving environmental impacts and the management accounting professional strictly keeps focusing on profitability, this mutual agreement between both parties is difficult to find (ibid.).

Another problem hindering increased collaboration between both professions is the lacking communication (IFAC, 2005). Since environmental management and management accounting originate from other professions, it is important to find a common wording to enable mutual understanding.

Finally, the uncertainty of interpreting environmental performance data restricts its popularity of applying it in internal decision-making processes. Since a decrease in environmental impacts can be caused through increased resource efficiency, it is difficult to delimit environmental management measures from general efficiency efforts originating from management accounting measures. On the other hand, it is still unclear how far an environmental management system causes an increase in turnover. (Müller-Christ, 2010)

While the effort of increasing resource efficiency represents a common ground of both professions, the collaboration is at risk in case profitability and environmental protection represent conflicting goals. In this context, Müller-Christ (2010) claims that companies shall declare strategic financial goals superior to strategic environmental goals. One reason for this declaration can be seen in the focus of environmental management systems on standardisation and formalisation of an environmentally-focused PDCA cycle. Hence, environmental management systems are unable to resolve possible conflicts between conflicting goals of profitability and environmental protection. (ibid.) These possible conflicts need to be recognised and resolved comprehensively.

2.5. Deficit analysis

The introduction of the conventional investment decision-making processes in companies revealed the differentiation between the phase of the investment appraisal and the phase of the actual investment decision. On the basis of this differentiation the focus of this thesis is on the most common investment appraisal methods as this phase represents the foundation for the actual investment decision.

Hence, the goal of the investment appraisal is to sketch a realistic picture of the expected profitability, cash flows or risk over the lifetime of the investment object so that the decision-maker can compare this to competing investment objects. The introduction of the most common investment appraisal methods revealed that each method investigates another aspect of the investment object. While the payback period focuses on the point of time till amortisation, the ROI sets the averaged relation between invested capital and expected profits. In addition, the comparison of costs or benefits represents basic financial assessments. Cost/benefit comparison, payback period and the ROI represent static investment appraisal methods and thus do not recognise the time value of money. However, their advantage can be seen in a simple and quick calculation that is easy to comprehend also to non-financial professionals.

With regard to the dynamic investment appraisal methods, the NPV records the point of time of cash inflows and cash outflows and transfers them via a discounting factor to the present value. In analogy, the CV transfers the cash flows of an investment to the end point of the investment object's lifetime. Therefore, NPV and CV represent the value of the investment object that is added to the company's value. In addition, the IRR provides the discounting factor leading to a zero NPV, which provides the decision-maker an impression about the sensitivity of the investment object. Hence, the IRR sets the relation of the investment and the future discounted cash flows and thus represents an indicator for the efficiency and quality of an investment.

Since no investment appraisal method is able to assess all relevant aspects, a set of indicators is needed for a comprehensive investment decision. While the investment appraisal is able to generate quantitative figures, the decision-maker also takes qualitative factors into consideration. The UVA represents a popular method to compose such a set. Nevertheless, the allocation of weightings to the corresponding sub-goals as well as the judgement of the utility values depend on subjective weightings and are in the focus of criticism.

In addition to the most common investment appraisal methods, modifications of conventional investment appraisal methods are discussed to assess their ability to integrate environmental impacts. The EPP and EROI represent environmental analogies to the payback period and ROI. Nonetheless, EPP and EROI differentiate with extending the boundary of assessment by taking into consideration the environmental aspects occurring in the production phase of the investment object. The problem, which practitioners are confronted with, is the lack of environmental data of this production phase.

Another problem is the absence of an environmental impact assessment within EPP and EROI. In addition, both methods are only able to assess one environmental aspect at a time. Therefore, a comprehensive environmental impact assessment cannot be conducted on the basis of EPP and EROI.

The third environmental investment appraisal method is the ENPV which mainly focuses on the opportunity to adjust the discount factor with the intention to influence the investment behaviour of the decision-maker. Nevertheless, finding an appropriate level of this environmental discount rate is a controversially discussed issue in literature. Hence, the common criticism notes that adjusting the discount factor overwhelms the ability of the discount rate which is originally intended to represent a trade-off between investing now or later. Furthermore, the management accounting professionals do not intend to answer macroeconomic questions or the ethics of inter-generational equity.

Evidence for the low popularity in applying modified investment appraisal method is represented by a study of Schaltegger *et al.* (2011a) revealing that only 9.7 percent of the surveyed companies apply environmental investment appraisal methods.

Besides discussing the investment process within companies, conventional investment appraisal methods and their modifications, the state of current academic knowledge regarding environmental impact assessment in companies is highlighted. The environmental management department aims for continuous improvement of the environmental performance of the company.

This continuous improvement involves the collection, monitoring and analysis of environmental data which is also referred to as environmental management accounting. In contrast to this, authors see the field of environmental management accounting as a subsystem or extension of conventional management accounting (compare Baumast, 2009). While this involves collaboration between environmental management and management accounting, a survey reveals a lack of such collaboration. Possible reasons can be found in missing communication as well as the inability of resolving conflicting goals.

Besides organisational issues, the data quality regarding the measurement of relevant environmental aspects, which build the basis for a subsequent impact assessment, remains an issue which needs to be solved by the installation of additional measurement technology. Hence, integrated environmental information systems provide an overview about environmental aspects but lack detailed insights on equipment level. In context of investment decisions, this lack concludes the problem of executing validity checks. In addition, different perspectives of financial and environmental management accounting professionals have impact on the scope of measurement. While financial management accounting is concerned with cost-related resource and emission flow, the environmental management accounting is interested in a wider scope due to compliance checks of given threshold values.

Finally, the instruments of assessing the environmental impacts are still under development. The immaturity of environmental impact assessment methods is expressed in their inability of offering reproducible and comparable results on the one hand and an increased complexity leading to high effort and a lack of comprehension at practitioners on the other hand.

This deficit analysis intends to assess the underlying reasons for the lack of application of environmental investment appraisal methods in practice. One main reason can be found in the weaknesses of EPP, EROI and ENPV resulting in a low degree of practical applicability. Besides organisational issues focusing on the collaboration between environmental management and management accounting professionals, the immaturity of environmental impact assessment methods can be regarded as main reason as well.

Therefore, it is necessary to develop a method that is able to overcome the weaknesses and problems identified in this deficit analysis. This integrated investment method needs to comprise an environmental impact assessment, which implies that all relevant environmental aspects are previously identified and measured. In addition, the method must represent a low degree of complexity to ensure that also non-professionals are able to comprehend the underlying rationale of the investment appraisal. This is especially important when regarding the cross-functional collaboration of environmental management accounting issues. Furthermore, the method needs to generate reproducible results which also provide the basis for comparison. Finally, the results need to be traceable and expressed in monetary terms to increase acceptance and thus successful practical applicability.

3. Method development

3. Method development

The current state of academic knowledge reveals in its concluding deficit analysis that the available environmental investment appraisal methods show a low popularity due to their lack of practical applicability. This chapter intends to identify and discuss additional methods that can serve as a basis for developing a new environmental investment method.

However, before discussing these additional methods, the basis for such a discussion needs to be determined. This basis is represented by a set of requirements according to which the methods are assessed. The set of requirements is composed by the results of the deficit analysis of the previous chapter on the one hand and the literature on environmental performance measurement on the other hand. Besides defining these requirements, the assessment criteria need to be determined as well to ensure a standardised evaluation procedure.

Therefore, this chapter is structured into three parts. The first part reveals the definition of requirements and the corresponding evaluation parameters. The second part introduces additional approaches which can function as a basis for further method development. These approaches are clustered into three groups – environmental cost accounting methods, flow-based cost accounting methods and additional methods of integrating environmental impacts. The second part also represents the evaluation of the approaches on basis of the previously defined requirements. Finally, the third part discusses the implications of the method screening and evaluation for the development of the new integrated investing method, before the interim results of this chapter are summarised and discussed in subchapter 3.4.

3.1. Determination of requirements

The discussion of environmental management accounting in the previous chapter revealed requirements with regard to measuring and monitoring all relevant environmental aspects. Hence, the physical flows of an investment object need to be predicted and their relevance needs to be assessed to compose an environmental inventory of all relevant environmental aspects associated with the investment object.

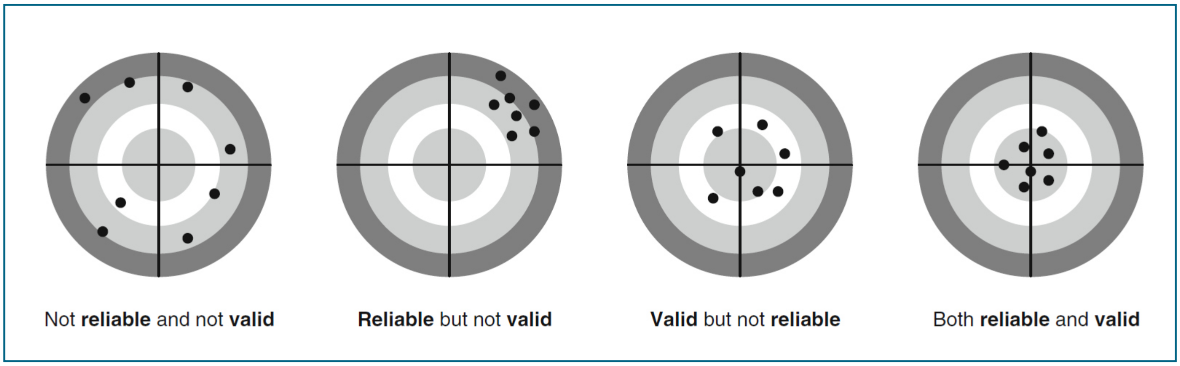
Furthermore, the continuous improvement of environmental performance in the context of environmental management requires an environmental impact assessment of the previously identified and quantified relevant environmental aspects. The results of this environmental impact assessment need to be reproducible and comparable to competing investment objects.

In addition, the deficit analysis revealed the problem that existing methods of assessing the environmental impacts are too complex and thus require a high timely effort on the one hand and lead to a limited degree of comprehensibility on the other hand. Hence, the requirement of comprehensibility is added to the set.

Besides the results of the deficit analysis, the academic literature on environmental performance measurement reveals additional requirements. Recker (2013) claims that validity and reliability are important attributes when assessing the scientific quality of methods. While reliability ensures that the application of the methods lead to the same reproducible results, validity ensures that the method serves the intended aim (ibid.).

Figure 14 shows the necessity for meeting both requirements by visualising the reliability and validity of fictitious measurement data.

Figure 14: Visualisation of different levels of reliability and validity of measurement results



Source: Recker, 2013:69

Prammer (2009) lists requirements concerning the application of environmental assessment methods in business practice. Besides a solid scientific basis, the methods need to be comprehensible and practicable to reach general acceptance (ibid.). In addition, Günther (2008) claims that the method needs to be applied within appropriate timely effort, which leads to increased practical applicability.

Another important requirement is the transparency of a method. Transparent methods enable decision-makers to understand the origin of the underlying data as well as the calculations and rationales behind the methods. This in turn increases the method's credibility. (Schwegler *et al.*, 2011)

In addition to comprehensibility and transparency of the method, the requirement of monetary evaluation aims at increasing the method's practical applicability. In this context, it is important to differentiate monetary evaluation from monetarisation. While monetarisation intends to assign a monetary value to an environmental impact, the term 'monetary evaluation' aims to express the result of a method in monetary values (FEM, 2003). The expression of the results in monetary values intends to increase the acceptance of the management since it represents a "*language that business managers understand*" (IFAC, 2005:41).

For a structured discussion in the course of this chapter, the requirements originating from the deficit analysis and the current academic literature are clustered into two groups. While one group represents requirements aiming at a sufficient degree of scientific quality, the other group of requirements aims for a successful practical application of the method.

The following table represents a summary of the requirements, which are defined in detail in the following subchapters:

Table 3: Summary of requirements as a basis for the method screening and evaluation

Scientific quality	Practical applicability
Environmental inventory	Comprehensibility
Environmental impact assessment	Transparency
Validity	Monetary evaluation
Reliability	

Source: Own representation

3.1.1. Requirements ensuring scientific quality

Environmental inventory

The targeted integration of environmental impacts bases on the method's ability to measure and quantify environmental aspects. Therefore, the environmental inventory requirement assesses whether all relevant environmental aspects are directly measured and quantified.

However, before assessing the methods in this chapter, three key elements, which are part of this requirement, need to be defined to ensure a uniform understanding of the requirement itself. These three key elements comprise:

- *environmental aspect*
- *relevance*
- *scope of measurement and quantification*

The International Organization for Standardization (ISO) provides a definition of environmental aspects in its norm addressing environmental management systems. According to the ISO (2009:11), an environmental aspect is an "*element of an organization's […] activities or products or services that can interact with the environment*". While this definition emphasises the interaction between the operations of a company with the environment, the ISO (2009) recommends the establishment of an input-output model as a basis for further measurement and quantification. The suggested inputs and outputs cover:

"- *emissions to air,*
- *releases to water,*
- *releases to land,*
- *use of raw materials and natural resources,*
- *use of energy,*
- *energy emitted e.g. heat, radiation, vibration,*
- *waste and by-products*" (ISO, 2009:26f.).

While conforming with the ISO regarding the recommended input-output model, the European Commission (2009) adds in its published regulation on the European Eco-Management and Audit Scheme (EMAS) additional environmental aspects.

These additional aspects include:

> "*- use and contamination of land […]*
> *- use of additives and auxiliaries as well as semi-manufactured goods [...]*
> *- transport issues […]*
> *- risks of environmental accidents and impacts arising, or likely to arise, as consequences of incidents, accidents and potential emergency situations.*" (European Commission, 2009:22)

The assessment of both standards on environmental management systems reveals an extensive list of possible environmental aspects. However, which environmental aspects need to be considered depends on the one hand on the investment object and on the other hand on the relevance of the environmental aspect. Hence, it needs to be defined when an environmental aspect can be regarded as relevant.

Concerning the definition of relevance, the ISO (2009:11) states that "*a significant environmental aspect has or can have a significant environmental impact*". While this definition connects environmental aspects with their impacts on the environment, it is not helpful in determining the relevance of environmental aspects.

Although the European Commission (2009:22) also describes this connection, further assistance in assessing the significance of environmental aspects is provided:

> "*- size, number, frequency and reversibility of the aspect or impact*
> *- existence and requirements of relevant environmental legislation*
> *- importance to the stakeholders and employees of the organisation*"

In conclusion, the relevance of an environmental aspect can be determined on the basis of several parameters such as physical quantities, environmental legislation or outcomes of stakeholder dialogues. In the context of this thesis, the relevance is determined according to the quantities of environmental aspects. Moreover, the proportion of the total measured and quantified environmental aspects is important when determining the relevance of environmental aspects.

In addition, the scope of measurement and quantification needs to be determined. In the context of this thesis, the scope is set on direct environmental aspects which can be measured on the company's site (gate-to-gate). Furthermore, the scope is set on the environmental aspects resulting from the operation of the analysed investment object and not on the environmental aspects resulting from its establishment or disposal.

Finally, the evaluation question regarding the environmental inventory requirement can be formulated as follows:

Are all relevant environmental aspects directly measured and quantified?

The following table summarises the evaluation parameters of the environmental inventory requirement with their corresponding definitions:

Table 4: Definition of evaluation parameters of the environmental inventory requirement

Symbol	Parameter	Definition
✓	Yes	All relevant environmental aspects of the analysed investment object are directly measured and quantified.
O	Partly	Either the most relevant environmental aspect or one representative environmental aspect summarising various environmental aspects (e.g. CO_2-equivalents) is directly measured and quantified.
✗	No	No environmental aspects are directly measured and quantified.

Source: Own representation

Environmental impact assessment

After the basis of the method's ability to measure and quantify environmental aspects is assessed, the concluding step is the environmental impact assessment. This step is important since the sole relevance of the environmental aspect does not provide any conclusion about the severity or damage to the environment. Hence, this requirement evaluates whether the analysed method is able to assess and to integrate the environmental impacts of the relevant environmental aspects.

However, before analysing the methods on the basis of this requirement, two parts need to be determined beforehand. First, the term 'environmental impact assessment' needs to be defined. Secondly, the differentiation between direct and indirect environmental impact assessment needs to be clarified. Finally, a definition of environmental impact assessment in the context of this thesis is derived.

The ISO (2009:11) defines an environmental impact as "*any change to the environment […], whether adverse or beneficial, wholly or partially resulting from an organization's […] environmental aspect*". While the definition of environmental aspects concentrates on the interaction between a company's operations and the environment, this definition highlights the consequences of such interaction to the environment. In this context, Prammer (2009) determines three major categories of environmental impacts:

- change of resource inventory
- change of material composition of the natural environment
- change of ecosystem and landscape

In addition, Prammer (2009) differentiates between direct and indirect environmental impacts. While direct environmental impacts cause changes to the environment by operations of the company itself, indirect environmental impacts are caused by suppliers or clients.

In the context of this thesis, the emphasis is set on direct environmental impacts, which is also in line with the gate-to-gate scope of the environmental inventory requirement. Moreover, the emphasis is set on the severity of the change to the environment and not on the type of environmental impact category and its detailed consequences. This emphasis is set in order to enable integration in investment decisions since a detailed description of the consequences would result in limited comparability of investment objects within the investment appraisal.

Finally, the question regarding the environmental impact assessment requirement can be formulated as follows:

Is the method able to assess the environmental impacts of the relevant environmental aspects?

The following table summarises the evaluation parameters of the environmental inventory requirement with their corresponding definitions:

Table 5: Definition of evaluation parameters of the environmental impact assessment requirement

Symbol	Parameter	Definition
✓	Yes	The method is able to assess the environmental impacts of the relevant environmental aspects.
×	No	The method is unable to assess the environmental impacts of the relevant environmental aspects.

Source: Own representation

Validity

The validity requirement assesses whether the methods analysed in this chapter serve the intended purpose. Hence, it needs to be verified that investment decisions based on the integrated investment method lead to an improved financial and environmental performance of the company. Finally, the investment decisions should support the company in achieving the strategic environmental and financial goals. In this context, the terms ‘financial performance’ and ‘environmental performance’ need to be determined.

With regard to financial performance, the definition focuses on the financial and commercial efficiency of the company and on its ability to add value to the total value of the company (Günther *et al.,* 2006). Hence, the literature on performance measurement lists several indicators and ratios to measure this efficiency. As a representative of a broad consensus Gladen (2011) lists among others indicators such as sales turnover, costs per product, profitability or liquidity. With regard to investment appraisals, the methods introduced in the previous chapter refer, amongst others to PBP, ROI, NPV, CV, IRR, etc. (Poggensee, 2011).

Concerning the definition of ‘environmental performance’ of a company, Günther *et al.* (2006) discuss eight different definitions provided in literature. As a result, the authors analyse two main perspectives. On the one hand, definitions of environmental performance concentrate on the activities of a company such as activities of the environmental management department. On the other hand, definitions concentrate on the total amount of environmental aspects of a company and their impacts on the environment. (ibid.)

The ISO (2000) established an international standard on environmental performance evaluation. Within this standard, environmental performance is defined as the result of “*an organization’s management of its environmental aspects*” (ISO, 2000:5). In close relation to the standard concerning environmental management systems, the environmental performance evaluation is described PDCA cycle aiming at a continuous improvement. This aspect is also addressed by Günther *et al.* (2006), who declare the reduction of environmental aspects of a company from one year to another as ‘environmental profit’.

In the context of this thesis, financial performance is defined as economic and commercial efficiency of a company. The determination of environmental performance is in line with the definition of financial performance. Hence, environmental performance is defined as the reduction of environmental impacts. In both cases, it is assumed that strategic financial and environmental company goals exist so that investment decisions can be taken with the aim to achieve these goals.

Therefore, the validity requirement intends to assess whether there is a correlation between the investment decision and the strategic environmental and financial goals of the company. This is the case, for instance, if the method assesses the financial and environmental efficiency of the investment object and if investment decisions aim to increase this efficiency.

In conclusion, the main question for the validity requirement can be formulated as follows:

Does the decision based on the integrated investment method lead to an improved financial and environmental performance of the company?

The following table summarises the evaluation parameters of the validity requirement with their corresponding definitions:

Table 6: Definition of evaluation parameters of the validity requirement

Symbol	Parameter	Definition
✓	Yes	The decision based on the integrated investment method leads to improved corporate financial and environmental performance.
✗	No	The decision based on the integrated investment method does not lead to improved corporate financial and environmental performance.

Source: Own representation

Reliability

The final requirement ensuring scientific quality assesses the reliability of the discussed methods in this thesis. Hence, the requirement analyses whether the method leads to the same results after repeating the calculations under the same circumstances and with the same assumptions (Recker, 2013).

Hence, the consistency of the results depends on the reproducibility of the method’s application. In conclusion, the method should reveal the same result if:

a) one person repeats the calculation of the method after some period of time or
b) two different persons conduct the method’s calculation independently (ibid.).

Transferred to this thesis, the reliability requirement assesses whether the investment decisions based on the method's results are the same, whether one person repeatedly conducts the calculation after some period of time, or whether two independent persons conduct the method's calculation separately.

In this thesis, the decision-maker is assumed to take investment decisions rationally. Furthermore, the reliability can be increased by a detailed description of applying the analysed methods and their underlying calculation. With such a detailed description, uncertainty in application is decreased as well as room for subjective judgement and interpretation leading to lower variation of results.

Thus, the question regarding the reliability requirement can be formulated as follows:

Does the method lead to the same result when repeating its underlying calculations?

The following table summarises the evaluation parameters of the reliability requirement with their corresponding definitions:

Table 7: Definition of evaluation parameters of the reliability requirement

Symbol	Parameter	Definition
✓	Yes	The method leads to the same result when repeating its underlying calculations.
✗	No	The method leads to different results when repeating its underlying calculations.

Source: Own representation

3.1.2. Requirements ensuring practical applicability

After the scientific requirements are determined, this subchapter focuses on the requirements regarding a successful practical application. However, it needs to be emphasised that the chances of a successful practical application of the method are increased if all scientific requirements are met. Nevertheless, the literature suggests additional requirements.

This subchapter bases on the assumption that practical application of the method is successful if the user of the method, who is in this case the management, accepts the developed method. The literature focusing on software development picks up this issue by describing acceptance tests as an approach to ensure a successful application of the developed software (Ricca *et al.*, 2009).

Ricca *et al.* (2009) describe common gaps between software developers and clients resulting in non-effective software products. The majority of the described gaps result in a lack of understanding of the software by the user and thus can be summarised under the term 'comprehensibility'. Besides a sufficient degree of comprehensibility of the method, Pointner (2010) adds the transparency of the underlying data as requirement of acceptance of a method. Finally, the third requirement assesses whether the method expresses its result in monetary terms. Since managers mainly think in monetary terms and base their decisions on monetary values, this requirement also aims to establish management acceptance.

Comprehensibility

The aim of this subchapter is to ensure management's acceptance of the method which consequently leads to a successful practical application. In this context, the comprehensibility of the method, especially to non-experts, is identified to be an important requirement for management acceptance.

Hence, the question assessing the comprehensibility requirement can be formulated as follows:

Does the method provide a sufficient degree of comprehensibility also to non-experts?

Milde (2009) defines comprehension as the ability to represent a message which enables a person to draw own conclusions. In order to achieve such ability, the research field of information science identifies a clear structure and complexity of communicated messages as main drivers for their comprehensibility (Weitlander *et al.*, 2013). In addition to these two drivers of comprehensibility, the language of the communicated content is regarded as vital. According to Weitlander *et al.* (2013) a balance between plain language and precise technical terms, which are complemented with graphical illustrations, supports the comprehension of the communicated content.

In this context, Milde (2009) refers to the comprehension concept which was originally developed by Langer, Schulz von Thun and Tausch in 1974. The concept assesses textual comprehensibility on the basis of four dimensions:

- Simplicity
- Arrangement and structure
- Briefness and conciseness
- Activating add-ons
  (Milde, 2009).

Based on the given definitions above, the comprehensibility requirement of this thesis is composed of the following sub-requirements:

- Clear and logical structure
- Low degree of complexity in calculations
- Concise language used for explanation

Concerning the evaluation parameters, the comprehensibility requirement is regarded as being met if all three sub-requirements are met as well. In case only one or two sub-requirements are met, the final comprehensibility requirement is evaluated as being partly met. The comprehensibility requirement is not met in case none of the sub-requirements could be met.

Hence, the following table summarises the parameters of the comprehensibility requirement:

Table 8: Definition of evaluation parameters of the comprehensibility requirement

Symbol	Parameter	Definition
✓	High	All sub-requirements are met ensuring a sufficient degree of comprehensibility also to non-experts.
O	Medium	Only one or two sub-requirements are being met, resulting in a limited degree of comprehensibility to non-experts.
✗	Low	No sub-requirement is met resulting in a low degree of comprehensibility to non-experts.

Source: Own representation

Transparency

The transparency requirement intends to support the objective of achieving management acceptance. With a sufficient degree of transparency, the developed method is likely to be accepted by management and thus to be applied in practice.

Hence, the question regarding the transparency requirement can be formulated as follows:

Does the method provide a sufficient degree of transparency?

However, before assessing the methods of this chapter, the term 'transparency' needs to be defined. Bogna (2008) defines transparency as an ideal situation in which all participants in a market have access to all relevant information. Nevertheless, the author also admits that this definition is an utopic situation. In addition, Svetlova (2010:83) defines transparency as "*the increased flow of timely and reliable economic, social and political information*". In this definition, transparency is used as a synonym for an increased disclosure of information. In this context, Stiglitz (2000:1466) even states "*transparency – another name for information*". The demand for information represents the shared core of all these three definitions.

Nonetheless, what the authors do not include in their definitions are the motivations behind this demand for information. In this regard, Stehr and Wallner (2010) identify a growing demand for public transparency with a moral and political motivation. The authors recognise an increasing demand for public participation in information flows and decision-processes. This participation bases on the motivation to push companies and politics to account for their responsibility towards the environment and the society. (ibid.)

Transferred to the context of business, Prat (2005) deals with the growing demand of transparency by referring to the principal-agent theory. Therefore, transparency is "*the ability of the principal to observe how the agent behaves and the consequences of the agent's behaviour*" (Prat, 2005:862). Obviously, the central motivation behind the increased demand for transparency in this context is control of the principal over the agent.

Another motivation can be seen in the opportunity to reconstruct and understand the reasons for decisions which were taken in the past (Svetlova, 2010). Bogna (2008) picks up this idea and even goes further by suggesting to augment the compulsory external financial reporting with voluntary information about the internal decision-making processes. In this context, Pointner (2010) suggests to publicly provide the relevant data with their sources and origins which have led to decisions.

While the motivations behind the demand for transparency vary from influence over control to understanding decisions in business, the motivation of fighting corruption pre-dominates the majority of literature on transparency. Sampson (2010:101) highlights the efforts of Non-Governmental Organisations (NGOs), such as Transparency International, on fighting corruption by “*naming and shaming*” corrupt processes, companies or states.

Nevertheless, Sampson (2010) also complains about the work of Transparency International by focusing on the Corruption Perception Index (CPI). This index is published annually and assigns a single indicator value of perceived corruption to each country. The author criticises the non-transparent way of assembling a single indicator value out of surveys, studies and journalists’ opinions. Due to missing standardised definitions on corruption and on the evaluation of the countries’ situation, the results of the CPI are questionable since room for manipulation is given. (ibid.)

This in turn, reveals another aspect of transparency which is the need for standardisation. Behrens and Fluthwedel (2012) claim that standardised processes increase comparability as well as reproducibility and thus lead to transparency and trust. Schäfermeyer *et al.* (2012) add the increased quality resulting from standardised processes to the list of advantages of transparency. Furthermore, the room for manipulation and subjective judgement is reduced by means of standardisation.

Transferred to this thesis, the requirement assesses whether the method provides a sufficient degree of transparency. Based on the definitions discussed in this subchapter, the assessment needs to evaluate whether all necessary and relevant information are available for the decision-maker. In addition, the origin and quality of data need to be assessed to ensure that they are publicly available and objectively measured. This in turn leads the way to the third sub-requirement aiming at the standardisation of the assessed methods. Highly standardised methods offer less room for manipulation and lead to comparable, reproducible results of high quality.

Therefore, the discussion about the definitions and the underlying motivations of transparency revealed the following sub-requirements:

- Relevance and completeness of information or data
- Origin and quality of information or data
- Degree of standardisation of the method

Regarding the evaluation parameters of the transparency requirement assessment, the requirement is met if all sub-requirements are met. In contrast, the requirement is not met in case none of the sub-requirements are met. In the event that at least one of the sub-requirements is met while others are not met, the transparency of the method is limited and thus evaluated with a ‘medium’ degree of transparency.

Hence, the following table summarises the parameters of the transparency requirement:

Table 9: Definition of evaluation parameters of the transparency requirement

Symbol	Parameter	Definition
✓	High	All sub-requirements are met ensuring a sufficient degree of transparency.
O	Medium	Only one or two sub-requirements are met, resulting in a limited degree of transparency.
✗	Low	No sub-requirement is met resulting in a low degree of transparency.

Source: Own representation

Monetary evaluation

The third requirement aiming to ensure practical applicability is the ability of expressing the results of the method in monetary values. Since practical applicability can only be achieved with management accepting the method, the monetary evaluation requirement represents a vital part of the assessment.

According to the IFAC (2005:41), the chances of practical application of environmental management methods increase with their ability to "*translate environmental performance into "cost and savings" language that business managers understand*". Hence, the IFAC (2005) argues for linking physical inputs and outputs with monetary values. In this context, Klaschka (2002) states that the perceived value of natural resources increases with expressing their values in monetary terms. Jasch and Schnitzer (2002) also note that monetary evaluation is the very basis for integrating environmental aspects in investment decisions.

This requirement intends to assess whether the method is able to express the calculated result in monetary terms. It is important to note that such an expression of results in monetary terms does not intend assigning a price to environmental impacts. Therefore, the definition of the IFAC (2005:45) holds that monetarisation is defined as "*the valuation of a use or damage in units of money*".

This differentiation between monetary evaluation and determining prices for natural resources is important since the latter involves unsolved weaknesses so far. In this context, Klaschka (2002) focuses on the problem of considering time in pricing natural resources. The author refers to the example of humus which needs between 100 and 300 years to build a thickness of about one centimetre (ibid.). Considering the price for one cubic metre of humus would result in a price which would be way higher than the market is willing to pay. Hence, Klaschka (2002) states that it is impossible to determine a price which is in consensus between the market and natural science. Schwermer (2007) adds to these weaknesses the inability of market prices to represent the environmental impact on natural resources.

Therefore, the question regarding the monetary evaluation requirement can be formulated as follows:

Does the method express its result in monetary terms?

The following table summarises the evaluation parameters of monetary evaluation requirement with their corresponding definitions:

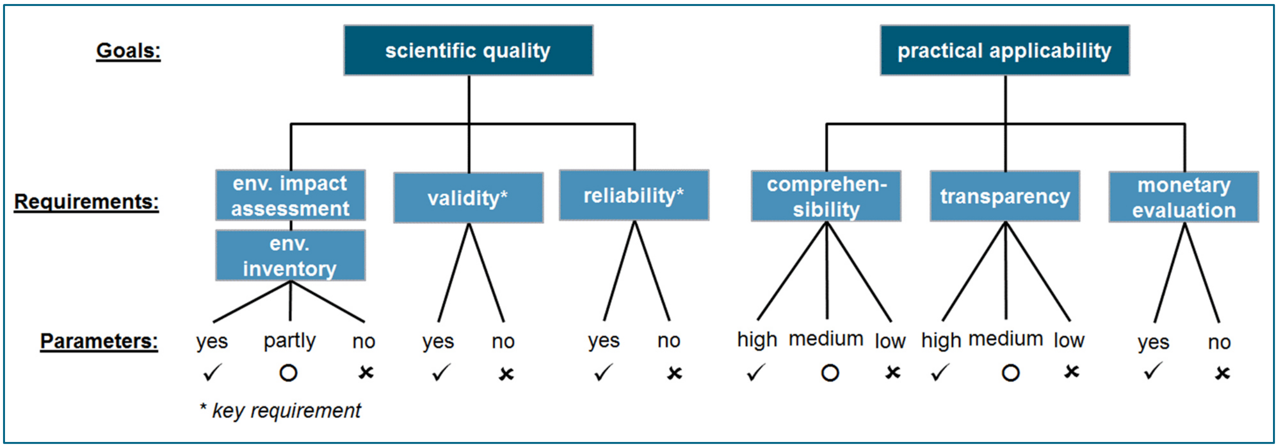
Table 10: Definition of evaluation parameters of the monetary evaluation requirement

Symbol	Parameter	Definition
✓	Yes	The method expresses its result in monetary terms.
×	No	The method does not express its result in monetary terms.

Source: Own representation

Finally, the previously defined requirements and their corresponding evaluation parameters for assessing the introduced methods within this chapter can be summarised in Figure 15. The requirements validity and reliability are highlighted since they represent key requirements. Without meeting these requirements, methods are likely to fail practical application, since the investment decisions based on the method do not improve the financial and environmental performance and the results cannot be reproduced after repeating the underlying calculations. While the importance of the two key requirements are emphasised, the other requirements are of equal importance.

Figure 15: Overview of requirements and evaluation parameters of this thesis



Source: Own illustration

After determination of the relevant requirements and the definition of the corresponding evaluation parameters, this chapter introduces methods which can serve as a basis for developing the new integrated investing method.

The introduction of additional methods is clustered into three groups. The first group discusses environmental cost accounting methods. The projection of costs represents a preparatory step in front of conducting investment appraisal methods. In case, environmental costs can be delimited from other operating costs of an investment object, a conventional investment appraisal method could be applied. Hence, environmental approaches are part of this chapter since a delimitation of environmental costs represents an indirect integration of environmental aspects in investment decisions.

The second group of introduced methods clusters the flow-based cost accounting methods. These methods aim to allocate operating costs to a flow model of production. Thus, the costs are directly connected with the environmental aspects of an investment object. Therefore, the integration of environmental aspects in investment decisions indirectly takes place, since environmental costs are delimited in a step prior to the investment appraisal method.

The third group of methods clusters additional methods which could not be categorised in one of the previous two groups. Within the third group, the methods of internalising externalities, environmental indicators as well as the VDI-guideline 3800 are introduced. While the latter represents a hybrid between delimitation of environmental costs and proposing a way of integrating environmental aspects in investment appraisals, the first two methods of this group intend to expand accounting systems by recording additional environmental costs or by representing additional indicators.

The discussion of the introduced methods, based on the previously set requirements, is located at the end of each group. In addition, a table summarising the results of all intermediate discussions and conclusions is located at the end of subchapter 3.2. This final discussion aims to identify the method meeting most of the requirements and therefore is best qualified to represent a basis for further method development.

3.2. Method screening and evaluation

3.2.1. Environmental cost accounting methods

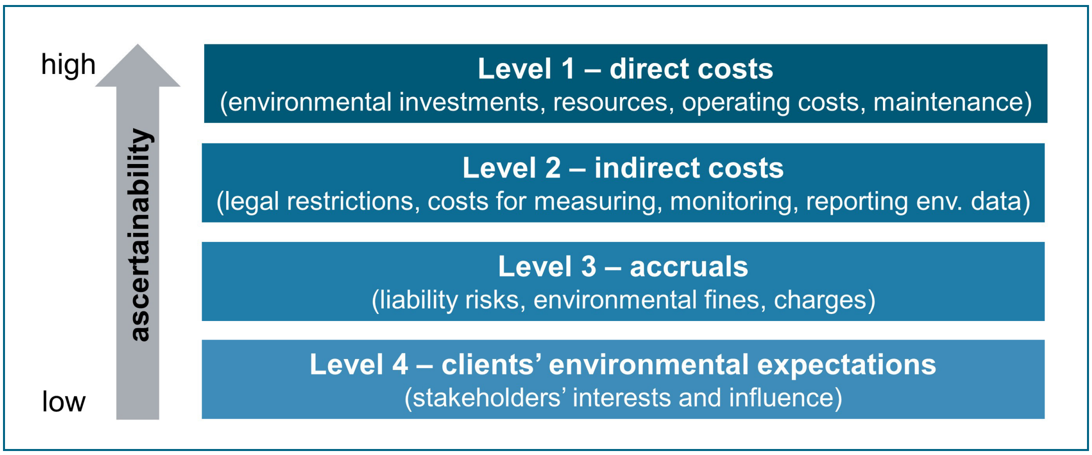
Before dealing with environmental cost accounting, it is important to discuss the various definitions of environmental costs in literature. As with the definition of environmental investments, there is no consensus regarding a definition of environmental costs in literature.

3.2.1.1. Defining environmental costs

Baumast (2009) defines environmental costs as the result of environment-related measures which are expressed in monetary units. While this definition demonstrates a rather broad character, the definition of the German Federal Environmental Ministry (FEM) focuses on the contextual systems within a company in which environmental costs can occur. Hence, environmental costs are defined as expenditures "*in connection with environmental management, environmental protection measures and environmental impacts*" (FEM, 2003:45) of a company. With describing the context in which environmental costs can occur, the FEM misses to provide a concrete definition of environmental costs as such.

A more comprehensive definition is contributed by the US Environmental Protection Agency (USEPA). In a training manual, the USEPA (1995) differentiates between four levels of environmental costs. The first level is represented by direct costs which are related to environmental investments, resources as well as operating and maintenance costs. The second level deals with hidden costs, which are difficult to measure (as illustrated in Figure 16). These costs can occur, e.g. for legal restrictions or the costs for measuring, monitoring or reporting environmental data. The third level deals with costs caused by liability risks that might occur through contaminated sites or environmental fines. These costs, which are typically booked under accruals, are often referred to as costs for omitted environmental protection. Lastly, the fourth level deals with costs caused by environmental client expectations. (USEPA, 1995)

Figure 16: Four levels of environmental costs according to the USEPA



Source: Own illustration based on USEPA, 1995

With the definition of the USEPA (1995), it is obvious that most of the environmental costs (levels two, three and four) are difficult to clearly identify as they are mostly ‘hidden’ in overhead or indirect costs. Even if the focus is on direct costs (level 1) such as environmental investments, there is still the problem of identifying the ‘environmental proportion’ of the investment object.

The International Federation of Accountants (IFAC, 2005) realised the issue of missing transparency within environmental costs and thus established an international guidance document on environmental accounting.

Table 11 illustrates the environment-related cost categories as identified by the IFAC:

Table 11: Environment-related cost categories, defined by the IFAC

1. Materials Costs of Product Outputs Includes the *purchase costs* of natural resources such as water and other materials that are converted into products, by-products and packaging.
2. Materials Costs of Non-Product Outputs Includes the *purchase (and sometimes processing) costs* of energy, water and other materials that become Non-Product Output (Waste and Emissions).
3. Waste and Emission Control Costs Includes costs for: *handling, treatment and disposal* of Waste and Emissions; *remediation and compensation* costs related to environmental damage; and any control-related regulatory *compliance* costs.
4. Prevention and Other Environmental Management Costs Includes costs for *preventive environmental management activities* such as cleaner production projects. Also includes costs for *other environmental management activities* such as environmental planning and systems, environmental measurement, environmental communication and any other relevant activities.
5. Research and Development Costs Includes the costs for *Research and Development* projects related to environmental issues.
6. Less Tangible Costs Includes both *internal and external* costs related to less tangible issues. Examples include *liability, future regulations, productivity, company image, stakeholder relations and externalities*.

Source: According to IFAC, 2005:38

In contrast to the definition of USEPA (1995), the IFAC adds details to the block of direct costs. Assuming that there are detailed information given for material costs as well as waste and emission control costs, this definition does not necessitate to expand the given cost information by an ‘environmental proportion’.

Environmental costs in context of this thesis

Hence, in the context of this thesis, the focus is set on direct and indirect costs, assuming that relevant cost information are already tracked by the internal accounting system. With the focus on direct and indirect costs, cost categories which are difficult to measure (e.g. accruals for liability risks or expected fines and charges, costs for stakeholder relations or costs for improving the company image, etc.) are excluded and thus outside the scope of this thesis.

With regard to the requirements of this thesis, the focus on direct and indirect costs increases the acceptance of the management. Costs can directly be traced back and can be tracked down in detail with an acceptable additional timely effort. However, the problem of identifying the environmental proportion within the direct and indirect cost pool is still present. Although various sources identify this problem, only a few authors suggest adequate solutions. The following subchapters present approaches trying to solve this problem.

3.2.1.2. Defining environmental cost accounting

After having dealt with environmental costs, the definition of environmental cost accounting sets the framework for the context and purpose of environmental costs. As with the definition of environmental investments or environmental costs, several definitions with different focus areas conclude a lack of consensus and consistent understanding of the term ‘environmental cost accounting’.

According to the FEM (2003:45), environmental cost accounting is the “*collective term for various methods, approaches and processes for determining environmental costs and showing them for internal or external company purposes*”. While this definition lacks naming the methods, approaches or processes, the aim of them is formulated specifically, which is to determine environmental costs. The second part of this definition focuses on the internal and external reporting, but again lacks naming the purposes precisely.

In addition, the definition by the IFAC (2005) refers to the same content with the term ‘environmental management accounting’ (EMA). According to the IFAC (2005:19), “*environmental management accounting is broadly defined to be the identification, collection, analysis and use of two types of information for internal decision-making:*

- *physical information on the use, flows and destinies of energy, water and materials (including wastes) and*
- *monetary information on environment-related costs, earnings and savings.*”

In contrast to the FEM, this definition highlights the environmental perspective and also adds details to the monetary perspective with the extension of environment-related earnings and savings. Furthermore, the IFAC (2005) only identifies the purpose for internal decision-making unlike the definition by FEM (2003), which also identifies external company purposes.

These differing definitions already show a lacking consensus. The IFAC (2005) picks up this issue by stating that every organisation has to determine its own interpretation of environmental management accounting. Hence, it is up to the management of a company to either decide for an EMA framework focusing on a narrow range of environmental costs or for broader interpretation also allowing strategic costs and benefits to be part of the accounting framework.

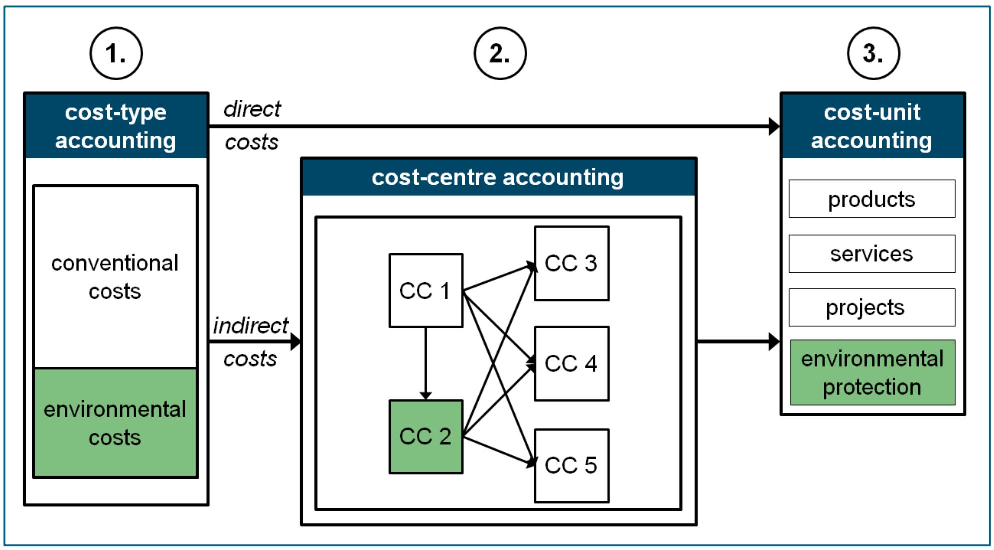
In the context of this thesis, the environmental cost accounting framework is determined according to the definition of environmental costs. Hence, environmental cost accounting focuses on direct and indirect costs that are already tracked by the internal management accounting system.

Loew *et al.* (2003) take over this narrow interpretation of an environmental cost accounting (see Figure 17). The intention is to identify the environmental costs within the already tracked costs of the accounting system. Hence, the first step is to differentiate the ‘environmental proportion’ within the cost-type accounting step. When purchasing raw materials, for instance, the additional costs for purchasing ‘environmental-friendly’ raw materials can be claimed as environmental costs. However, it is not always obvious to identify and clearly differentiate environmental costs within the cost pool. Hence, additional administrative costs occur for the identification of environmental costs. (ibid.)

The second step allocates the identified costs to the cost centres. Loew *et al.* (2003) suggest establishing a cost-centre for end-of-pipe measures to allocate all overhead costs, related to end-of-pipe measures, according to the cost-units, causing the necessity for these end-of-pipe measures. Depending on the production design of the analysed plant, such an allocation might be complex and not obvious in every case. In addition, the problem of identifying integrated environmental protection measures is still a matter of academic debate.

The third step represents the cost-unit accounting which provides the basis for internal decision-making. Within this step, direct costs of the cost-type accounting step as well as the allocated indirect costs of the cost-centre accounting step get summarised among various items. These items are established according to the management’s preference of analysis. Hence, the management might want to analyse, for instance, which costs occur for environmental protection and how these costs are composed. (ICV, 2010)

Figure 17: Illustration of an environmental cost accounting system



Source: Based on ICV, 2010:22

According to the FEM (2003), three benefits of establishing an environmental cost accounting framework can be identified. First, tracking environmental costs helps to visualise the environmental proportion and thus helps to integrate environmental aspects in the decision-making process within companies.

Therefore, a cost-effective implementation of investments in environmental protection can be ensured. Second, environmental cost accounting can reveal so-called ‘win-win situations’ in which an improvement in environmental performance concludes cost reductions. Finally, strategic environmental goals of companies can be tracked and communicated for marketing products with an improved environmental performance. (ibid.)

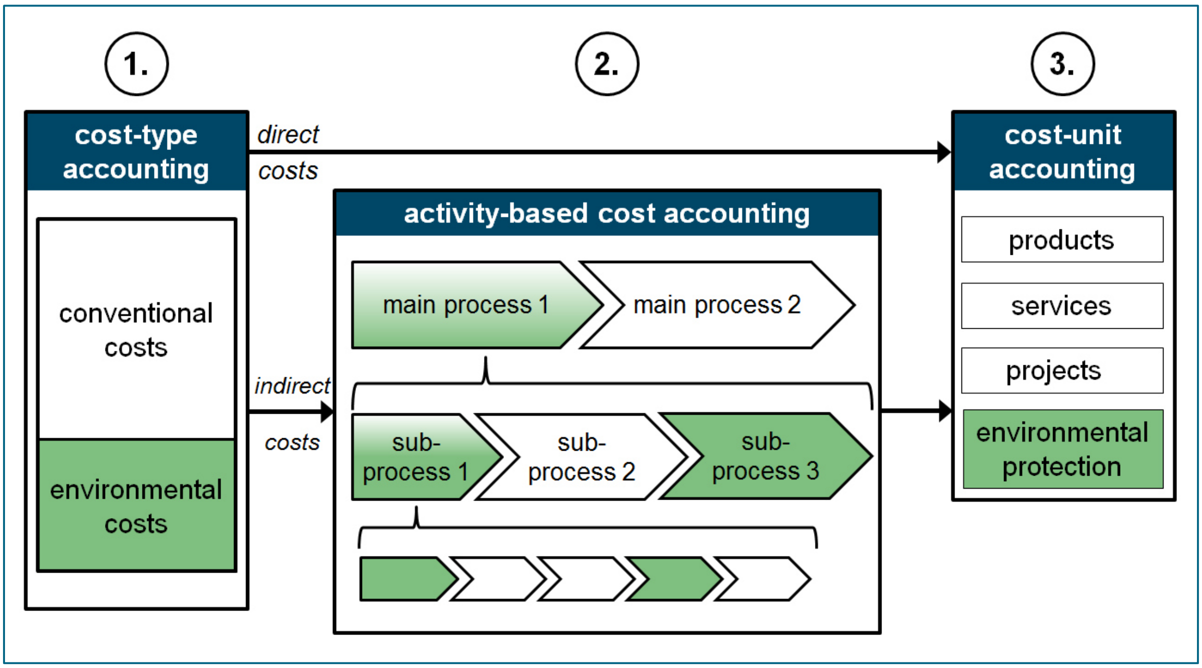
While a well-established environmental accounting framework reveals several benefits, the biggest challenge can be seen in its establishment. It needs to be analysed, for instance, whether the additional administration costs for the identification of environmental costs justify the resulting benefits of these insights.

In addition, the IFAC (2005:26) criticises that “*many types of environment-related cost information are not found in the accounting records*”. This criticism can be extended by pointing at the environmental performance. Tracking environmental costs and increasing or decreasing these costs does not necessarily lead to an improved environmental performance.

3.2.1.3. Environmental activity-based cost accounting

The basic concept of activity-based costing (ABC) is to allocate overhead costs to defined processes, which are subdivided in main processes and sub-processes, according to common cost drivers (Walter and Wünsche 2013). Loew *et al.* (2003) extend this concept with the application on environmental costs. Hence, costs for environmental management or environmental protection measures, such as end-of-pipe measures, get allocated to the main and sub-processes of a company (see Figure 18).

Figure 18: Illustration of environmental activity-based cost accounting



Source: Based on ICV, 2010:23

One advantage can be seen in the fact that the allocation is based on the polluter pays principle (Loew *et al.*, 2003). Therefore, processes and the resulting products with less environmental significance are accredited with less environmental overhead costs than processes and products with high environmental significance. Although this allocation is more realistic, the benefit for the environmental management is questionable. As a consequence, every process owner would aim for a reduction of the apparently avoidable environmental cost allocation.

On the one hand, the environmental impact would decrease since processes would become more environmentally friendly (e.g. by increasing resource efficiency). On the other hand, however, the remaining fixed overhead costs for environmental management would still need to be allocated. In conclusion, the paradox situation can occur that environmental cost allocation stagnates (or even increases for the remaining cost centres), although processes have become more environmentally friendly.

In addition, the allocation of environmental costs on cost centres comprises the message that costs for environmental protection are avoidable costs. While this is a positive aspect on one side since management and process owners would be sensitised for environmental protection, the communication via costs neglects the positive aspects and the accompanying chances of environmental protection.

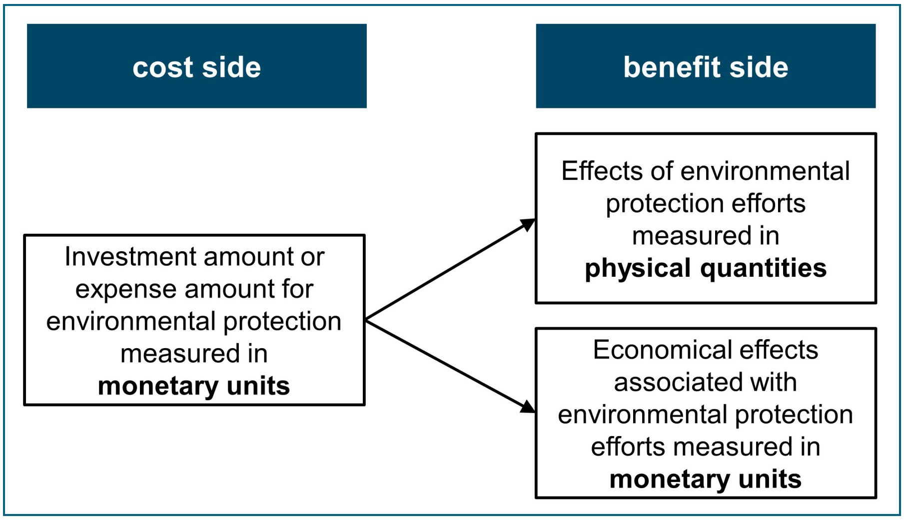
3.2.1.4. Japanese environmental accounting guidelines

In the year 2000, the Ministry of the Environment in Japan (MEJ) published first results of a working group that assessed the potential of implementing an environmental accounting framework in companies (MEJ, 2000). Two years later, a first version of the Environmental Accounting Guidelines was published followed by an updated version in 2005.

In a survey, Konkubu and Nashioka (2005) assess the degree of implementation of the Environmental Accounting Guidelines. They reveal that over 187 companies that are listed on the Tokyo Stock Exchange have introduced "*environmental accounting either for external disclosure or internal management*" (ibid.:327).

According to the MEJ (2005:3) environmental accounting "*aims at achieving sustainable development […] and pursuing effective and efficient environmental conservation activities*". While the achievement of sustainable development represents a broad goal, the pursuit of efficient and effective environmental conservation activities is realised with the help of quantitative measurements in monetary values or physical units. Hence, the structure of the environmental accounting framework as described by the MEJ is illustrated as follows:

Figure 19: Illustration of Japanese Environmental Accounting Framework



Source: Based on MEJ, 2000:6

Regarding the cost side of the environmental accounting framework, the MEJ (2005) differentiates between investments and expenses. In this context, environmental investments are defined as "*the expenditures of investments a company spends on depreciable assets for the purpose of environmental conservation*" (MEJ, 2005:13). Since investment-related costs are listed on the cost side, the amount for acquiring the investment is not listed but instead the associated depreciation of the investment object. Hence, the accumulated depreciation at the end of the investment object's lifetime represents the original acquisition value.

In contrast to investments, expenses on the cost side are defined as "*the company's overall expenses and […] the amounts used for the purpose of environmental conservation*" (MEJ, 2005:13). Furthermore, the corresponding costs are differentiated in more detail within seven categories, which are listed in the table below:

Table 12: Categories of corresponding costs to business activities

Category	Content
Business area cost	Environmental conservation cost to control environmental impacts, which result from key business operations within the business area
Upstream/downstream cost	Environmental conservation cost to control environmental impacts, which result from key business operations upstream or downstream
Administration cost	Environmental conservation cost stemming from administrative activities
R&D cost	Environmental conservation cost stemming from R&D activities
Social activity cost	Environmental conservation cost stemming from social activities
Environmental remediation cost	Cost incurred for dealing with environmental degradation
Other cost	Other costs related to environmental conservation

Source: MEJ, 2005:14

It is noticeable that these seven cost categories represent a comprehensive view on environmental costs. Especially, the category concerning upstream and downstream costs emphasise the company's responsibility over the whole life cycle of the product. However, collecting data on upstream and downstream operations is regarded as difficult due to the lack of reliable data (Li and Lin, 2006). These costs represent external costs which are internalised at this point. Nonetheless, these internalised costs cannot be found in financial statements as they are not backed-up by any real cash flows.

The guidelines also deal with the problem of identifying environmental costs and separating them from 'ordinary' costs. Hence, the MEJ (2005) introduces the terms 'direct costs' and 'complex costs'. While direct costs can be entirely attributed to costs related with environmental protection, complex costs partly serve environmental protection but also serve other purposes (e.g. increasing quality, decreasing operating costs, increasing productivity, etc.).

In addition to this separation of terminology, the MEJ (2005) suggests three methods to aggregate complex costs. The first method is called 'difference aggregation' and can be used if the exact proportion of environmental protection of an investment (e.g. special filter systems) is given. Hence, the difference of this environmental component to the remaining investment value is aggregated as environmental costs.

The second method suggested for the aggregation of complex costs is called 'allocation aggregation'. The example that is provided by the MEJ (2005) deals with the allocation of personnel costs. Hence, the "*distribution rate for hours spent on environmental conservation activities versus those spent on other tasks*" can serve as a basis for aggregating complex costs (ibid.:24).

Finally, the third category is called 'simple methods' and lists three additional suggestions how to aggregate complex costs. While one suggestion is not to aggregate complex costs if environmental costs represent a minor proportion, the total costs can be aggregated in case environmental costs represent the major proportion. The third suggestion under the 'simple methods' category comprises setting a percentage, based on an expert's opinion which indicates the proportion of environmental costs. (ibid.)

Concerning the benefit side of the environmental accounting framework, the MEJ (2005) differentiates between the environmental conservation benefit and the economic benefit which is caused by the environmental conservation efforts. While the benefit of environmental conservation is measured in physical units, the associated economic benefit is measured in monetary units.

With regard to the physical units of the environmental conservation benefit calculation, the total volume of environmental aspects of the current accounting period is deducted by the total volume of environmental aspects of a base period, which is usually represented by the previous accounting period. The guidelines suggest measuring the environmental aspects via environmental performance indicators. While exemplary environmental performance indicators are provided, it is suggested to define indicators which are relevant to the company's processes and products. (ibid.)

According to the MEJ (2005:32) the economic benefits are defined as "*benefits to a company's profit as a result of carrying forward with environmental conservation activities [which] are measured in monetary value.".* Therefore, the economic benefits can occur through two options. On the one hand, economic benefit can be generated by increasing revenue, for instance, by selling waste for recycling. On the other hand, economic benefit can be generated by reducing costs through increased resource efficiency.

3.2.1.5. Evaluation of environmental cost accounting methods

The literature reveals that there is no consensus on a comprehensive definition of environmental costs. In addition, environmental costs can comprise elements that are hardly measurable which concludes the focus on direct and indirect costs. Hence, the goal is to identify the environmental proportion within the already tracked direct and indirect costs of the internal management accounting system. However, the problem of delimitation remains as central point of discussion.

As with the definition of environmental costs, there is lack of consensus on defining environmental cost accounting. Thus, this definition depends on how broad or narrow the environmental costs are defined in the first step. In conclusion, every organisation has to determine its own interpretation of environmental management accounting. In the context of this thesis, environmental cost accounting focuses on the management of the environmental proportion of direct and indirect costs that are already tracked by the internal accounting system.

In addition, the literature on environmental cost accounting focuses on the correct allocation of indirect costs. On the one hand, it is suggested to establish a cost-centre for end-of-pipe measures to allocate indirect environmental costs. On the other hand, the suggested environmental activity-based costing concept intends to allocate indirect costs according to the production processes. In both cases, indirect environmental costs are allocated according to the polluter pays principle, which increases the environmental awareness and establishes an environmental incentive system. Nevertheless, the correct monitoring and allocation of indirect environmental costs is not directly linked to an environmental impact assessment. In conclusion, a well-functioning environmental cost accounting framework does not necessarily lead to an improvement of environmental performance.

The Japanese Environmental Accounting Guidelines represent a comprehensive approach. Besides detailed suggestions for the determination and delimitation of environmental costs, the guidelines also highlight the physical and monetary benefits resulting from environmental cost accounting. In addition, the guidelines are designed for internal and external reporting purposes. Hence, the focus on reporting raises the question whether the guidelines also qualify for internal environmental cost controlling.

The guidelines were introduced in 2002 with an updated version in 2005. Since then, no updates were published. Furthermore, the guidelines have not attracted attention outside Japan so far. A reason for that can be found in the high degree of subjectivity within the suggested solutions for the delimitation of environmental costs.

The suggestion of listing benefits in form of measured physical quantities represents the basis for an environmental impact assessment. Nevertheless, an actual environmental impact assessment is also not intended within the Japanese Environmental Accounting Guidelines.

Regarding the *environmental inventory* requirement, the method should directly measure and quantify all relevant environmental aspects. The introduced methods have in common, that they assign costs to environmental aspects. However, not all environmental aspects generate costs to the company and thus are externalised. Furthermore, the amount of the recorded environmental aspects is not in the focus of the introduced environmental cost accounting methods but the amount of their associated costs.

Due to the focus on costs caused by environmental aspects an *environmental impact assessment* is not intended by the discussed environmental cost accounting approaches. In addition, the amount of environmental costs does not correlate with the environmental impact which is why this requirement is not met.

The *validity* requirement analyses whether the implemented method leads to an improved financial and environmental performance of a company. Since an increase or decrease of environmental costs is not correlated with the environmental performance of a company, the validity of environmental cost accounting approaches is not given.

With regard to the method's *reliability*, the requirement assesses whether the method leads to the same result when repeating its underlying calculations. The unsolved problems regarding the allocation of indirect costs as well as the delimitation of environmental costs for integrated environmental protection measures comprise a high chance that the discussed methods do not produce the same result after repeating their calculations. Hence, the reliability requirement is not met.

Concerning the *comprehensibility* requirement, the discussed environmental cost accounting approaches comprise a clear and logical structure as it relates to already existing and established accounting approaches. The degree of complexity of the environmental cost accounting framework corresponds with the complexity of the production system. In addition, the problem of allocating environmental overhead costs to production processes complicates the practical application. Hence, the sub-requirement of a low degree of complexity is not met.

However, the discussed environmental cost accounting approaches contain a concise language, which is in the style of conventional accounting language. While the sub-requirements of a 'clear and logical structure' as well as a 'concise language' are met, the sub-requirement of a 'low degree of complexity' is not met. As a consequence, the environmental cost accounting approaches are evaluated with limited (i.e. medium) comprehensibility.

Regarding the *transparency* requirement, the associated sub-requirements comprise the relevance and completeness of data, their origin and quality as well as a sufficient degree of standardisation. While the origin and quality of data is ensured due to the consideration of already tracked costs within the accounting system, the relevance and completeness of data is questionable. Due to the lack of market prices for some environmental aspects, the costs of these aspects cannot be determined as well. Hence, the relevance and completeness is not met. Furthermore, the degree of standardisation of determining environmental costs should offer more precision to reduce the opportunities of subjectively determining environmental costs. Since two sub-requirements are not met, the transparency is limited, resulting in a medium transparency for environmental cost accounting approaches.

The third requirement assesses the method's ability to express the results in *monetary terms*. Due to the focus of environmental cost accounting approaches to determine the amount of environmental costs, this requirement is met.

The table below provides an overview of the requirement evaluation results for the discussed environmental cost accounting methods:

Table 13: Overview of the requirement evaluation for environmental cost accounting methods

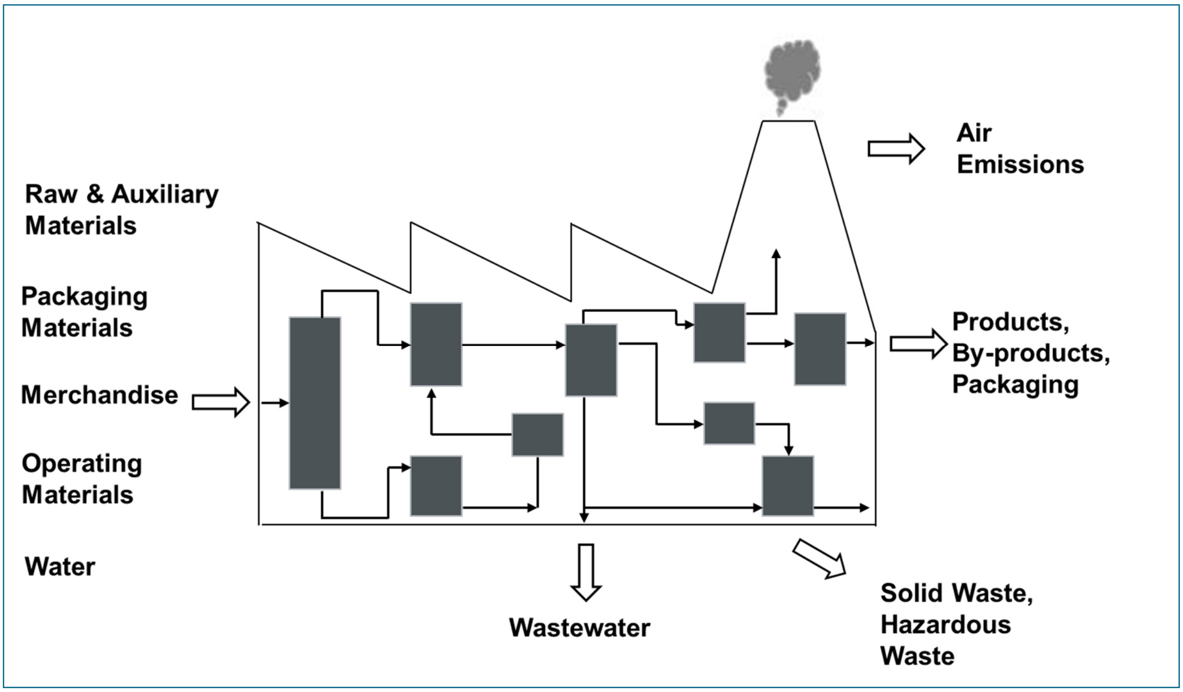
Goal	Requirement	Evaluation	
Scientific quality	Environmental inventory	No	×
	Environmental impact assessment	No	×
	Validity	No	×
	Reliability	No	×
Practical applicability	Comprehensibility	Medium	○
	Transparency	Medium	○
	Monetary evaluation	Yes	✓

Source: Own representation

3.2.2. Flow-based cost accounting methods

This subchapter discusses cost accounting approaches focusing on costs associated with physical inputs and outputs in form of material, energy, water, emission or waste flows within a given production system. These input and output flows are represented in a flow chart that is congruent to the production system of a company (see Figure 20). Besides the illustration in form of a flow chart, flows are expressed in form of a mass balance to ensure that all physical flows have been recorded. (IFAC, 2005)

Figure 20: Simplified illustration of a flow chart of a production system



Source: IFAC, 2005:31

Flow-based cost accounting approaches base on the fact that material-related costs often represent the biggest cost factor within manufacturing industry. In this context, Strobel and Müller (2012) state that the average proportion of material costs is over 56 percent of total costs in the German automotive industry. In addition, material- and energy-related flows can be linked to environmental impacts of a company (Loew *et al.*, 2003). Hence, flow-based cost accounting approaches can indirectly function as environmental accounting approach.

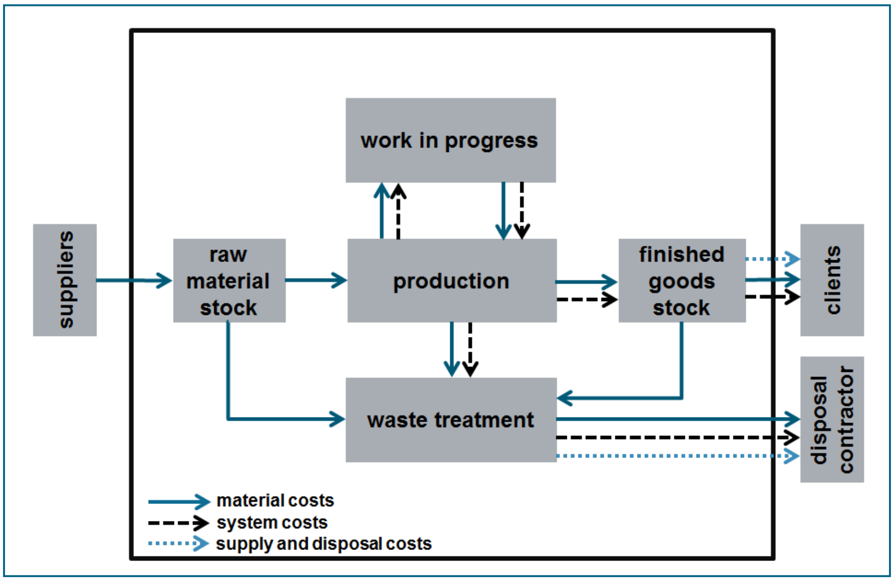
3.2.2.1. Material flow cost accounting

The IFAC (2005) defines material flow cost accounting as system that traces material flows through material management steps with material balance numbers attached. These material management steps comprise amongst others procurement, delivery, inventory, internal distribution and product shipping. However, also material management steps, which are not leading to a finished product (such as waste collection, recycling, treatment and disposal), are included in material flow cost accounting. (ibid.)

While the IFAC (2005) focuses on costs for materials only, Loew *et al.* (2003) extend this concept by system costs and costs for supply and disposal. Regarding material costs, the actual market value of the processed material is recorded. To avoid double-counting, it is necessary that materials are only recorded once. System costs comprise all costs associated with handling, storage or processing of the material. The third cost category represents costs for supply and disposal. Within this category, costs for supplying the finished goods to the client as well as costs for disposal or waste water treatment are included. (ibid.)

These three identified cost categories and the associated costs can be visualised in a simplified flow chart based on the production system of a company, as given in the following figure:

Figure 21: Simplified flow chart of the production system of a company



Source: Based on Loew et al., 2003:88

Combined with the associated cost data, the aim of the material flow visualisation is to increase the understanding and transparency of the materials cost pool. In addition, it is possible to identify the proportion of material which does not end up in the product but instead in disposal processes. Hence, decision-makers can derive measures for reducing material flows for disposal. In addition, inefficient production processes can be identified and improved. (Strobel and Müller, 2012) In conclusion, material flow cost accounting provides the basis for improving material efficiency which in turn improves the eco-efficiency of a company.

Another tool that is used in this context is the flow cost matrix (see Table 14). It summarises the costs per cost category or cost-type. While the flow cost matrix foregoes the visualisation of material flows, the intention to identify inefficient processes remains the same. (Loew *et al.*, 2003) On the one hand, the sum of flow costs per category or cost-type can be retrieved quickly. On the other hand, however, the source of inefficiency cannot be traced back via the flow cost matrix.

Table 14: Flow cost matrix of a production system

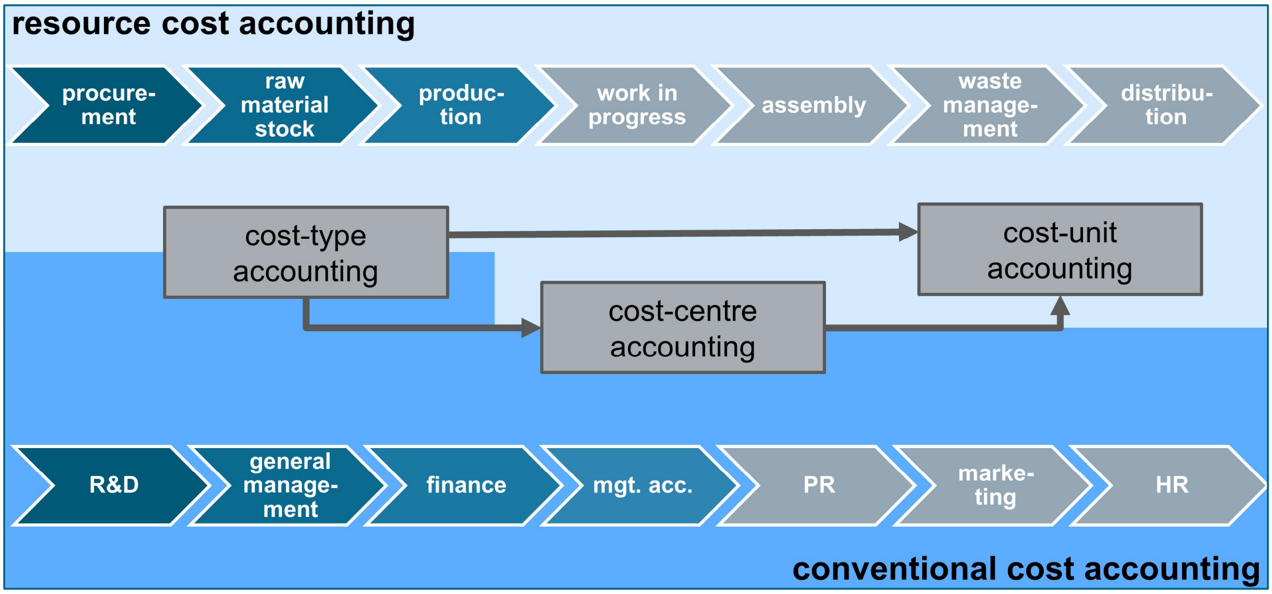
(in million €)	Material costs	System costs	Supply & disposal	Sum
Product	120	25	0.2	**145.2**
Packaging	40	25	2.5	**67.5**
Material losses	21.5	6.4	1.5	**29.4**
Sum	**181.5**	**56.4**	**4.2**	**242.1**

Source: Based on Loew et al., 2003:88

3.2.2.2. Resource cost accounting

Resource cost accounting intends to match the flows of a production process with the already existing cost accounting framework (see Figure 22). The Efficiency Agency of North Rhine-Westphalia, Germany (EFANRW, 2003) therefore describes a seven step plan to implement resource cost accounting in companies. This implementation plan can basically be split up into three parts. While the first part concentrates on the analysis of the actual situation and the establishment of a flow chart of the existing production processes, the second part concentrates on data collection and the quality of collected data. After creating the resource cost accounting framework, the third part focuses on detecting inefficient processes and their improvements. (ibid.)

Figure 22: Resource cost accounting and conventional cost accounting

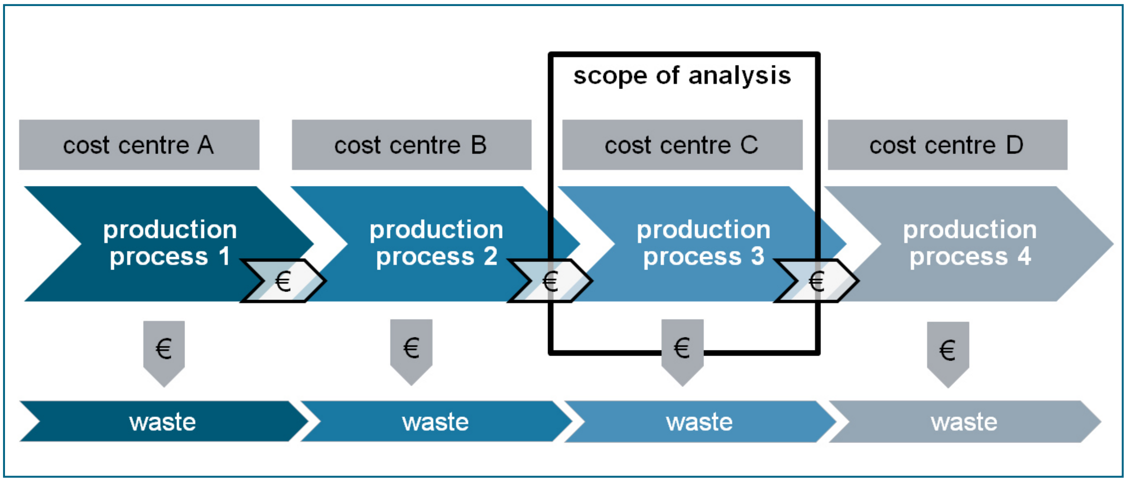


Source: Based on EFANRW, 2003:8

In contrast to material flow cost accounting, the focus is set not only on material-related costs but also on the processes of the production system. Hence, besides costs for material, energy or waste, also costs for machine hours or personnel costs are taken into consideration. In conclusion, resource cost accounting represents an extended approach compared to conventional cost accounting. (ibid.)

Figure 23 shows that cost-centres are allocated to production processes. Hence, the material, energy and waste flows are allocated to each production step and cost-centre. The underlying intention is to allocate costs to its originator. This does not only enable detecting inefficient processes but also detecting the originator of these processes. (ibid.)

Figure 23: Scope of analysis within resource cost accounting



Source: Based on EFANRW, 2003:7

The resource cost accounting approach represents an extension of conventional cost accounting by a flow-based view. In contrast to material flow cost accounting, additional cost-types (such as machine hours or personnel costs) are included in the scope of analysis. However, the effort of implementing resource cost accounting is considerable since additional data needs to be collected and timely effort in the quality of the collected data is considered to be high in the beginning.

Nevertheless, Tschandl (2012) reports first experiences which reveal that over 40 percent of resources do not end up in the produced product. Hence, resource cost accounting represents a helpful accounting approach to improve resource efficiency in production. Again, improved resource efficiency indirectly improves the environmental impact of a company. Yet, resource cost accounting fails to provide an environmental impact assessment.

3.2.2.3. Materials-only costing

Materials-only costing aims for separating material costs from manufacturing labour costs. As a consequence, two cost blocks provide detailed insights in the total manufacturing costs. In conclusion, these insights help to analyse the underlying cost drivers of total manufacturing costs. The baseline argumentation with materials-only costing, however, is that manufacturing labour costs are only 10 to 30 percent of total manufacturing costs. Hence, the focus should be set on direct material costs with the aim to identify resource efficiency potentials. (Loew *et al.*, 2003)

Providing that a flow chart, including all necessary material flow information, already exists, the effort for introducing materials-only costing is relatively low as the already existing total manufacturing costs record is split up into material costs and manufacturing costs. Nevertheless, the focus of materials-only costing is set on resource-efficiency rather than on environmental protection due to a missing environmental impact assessment. In addition, the remaining resources and emissions necessary to manufacture a product are ignored, which is leading to an incomplete analysis. Another weakness is the fact that the materials-only costing calculation is a separate calculation besides the regular cost accounting and this requires additional timely effort (ibid.).

3.2.2.4. Waste material accounting

Waste material accounting bases on the flow model of a production system but instead of focusing on material- or energy-related flows, the focus is set on waste. Loew *et al.* (2003) define waste as unwanted output of production processes containing, solid waste, waste water, air emissions, waste heat and packaging. Applied on waste material costing, no cost would occur assuming a closed-loop production system with only finished goods as single output. (ibid.)

Waste material costs are divided into three categories. The first category contains the costs of procuring waste material, which result from multiplying the amount of waste material by its original purchase price. The second category is called costs for producing waste material. It contains the costs of handling the material until it is declared as waste material, which includes for instance the costs for personnel handling the material and depreciation. The third category within waste material accounting refers to the disposal of waste. Hence, it contains costs for waste management such as separation, waste water treatment and filtration of air emissions. (ibid.)

The execution of waste material cost accounting assumes an already established flow chart including its mass balances. Hence, the first step comprises the allocation of the disposal costs including costs for waste management and waste water treatment. The next step comprises the imputed costs which are related to waste treatment. These costs contain depreciation for environmental protection facilities as well as personnel costs for employees running and maintaining these facilities.

The concluding step deals with the determination of loss of material and waste occurring during the production process. This step contains the multiplication of purchasing prices of the raw material with the amount of waste. Furthermore, the costs for processing the raw material until it is declared as waste (including machine and personnel costs) are added. Finally, waste material accounting aims to derive the waste material costs per product within the cost-unit accounting step. (ibid.)

Waste material accounting bases on an early idea which can be found in the Brundtland Report (1987:184), which claims that "*pollution is a form of waste and a symptom of inefficiency in industrial production. When industries recognise pollution as a cost, they are sometimes motivated to make investments in improved products and processes*". Waste material accounting picks up this idea and presents a first solution. With the establishment of waste materials within the cost-unit accounting, inefficiency is represented with an indicator in form of costs. Thus, the obvious aim is to decrease waste material costs towards zero, which supports the understanding and therefore the acceptance of the management.

The focus within waste material accounting is – in analogy to materials-only costing – on resource efficiency within the production system. Again, no environmental impact assessment is included. Hence, environmental protection is only regarded as secondary goal. Furthermore, the execution of waste material accounting assumes a flow chart including information of waste flows within the production system. The establishment of such a detailed flow chart is connected with a high technical and timely effort.

In addition, the resource scarcity of precious metals, for instance, can turn this approach upside down. In case of the opportunity that waste can also be sold to external companies, efforts for increasing efficiency are absent since income can be generated with this kind of waste anyway. In this case, the environmental protection moves from being a secondary goal to a tertiary goal.

3.2.2.5. Evaluation of flow-based cost accounting methods

The previous subchapters discussed prominent methods with regard to flow-based cost accounting methods. All introduced methods have in common that they base on a flow model of the production system. The introduction of such a flow model is associated with an enormous timely effort. Only with cross-departmental collaboration, the amount and direction of resource flows can be determined. Experiences of first projects in practice show that measuring points (i.e. energy metres, water metres, or the like) need to be installed first on equipment level. Depending on the scope and the complexity of the production system, software solutions need to be designed and applied to manage the various installed measuring points. (Loew *et al.*, 2003)

However, the collection of the data represents a first step which is followed by validity checks to ensure sufficient data quality. In this step, the mass balances of the production processes help to determine inconsistencies. (ibid.) Finally, the established flow model is connected to the associated costs. Especially in the context of the allocation of costs, the underlying key of allocation can represent a matter of discussion due to subliminal inter-company politics. In this case, the effort of implementation increases as well as the risk that the resulting cost structure does not exactly fit to the reality of the production system.

Besides the establishment of a resource flow model, the management and maintenance represents an ongoing challenge, especially for frequently changing and complex production systems. In this context, Loew *et al.* (2003) constitute that flow-based accounting systems are limited by the complexity of the production system since the effort for establishing and maintaining exceeds its benefit at a certain point.

The introduced environmental cost accounting approaches face the problem of identification of the environmental proportion within integrated measures for environmental protection. In contrast to that, flow-based cost accounting approaches circumvent this problem with the focus on material and energy flows. An additional contrast can be identified in the perception of environment-related costs. While with environmental accounting approaches, additional costs are identified due to environmental protection measures, flow-based cost accounting aims for increasing resource efficiency resulting in a ‘win-win situation’.

Strobel and Redmann (2002:72) state that “*materials value orientation is the core of flow cost accounting*”. This quote sums up the main similarity of the introduced flow-based cost accounting approaches. While material flow cost accounting represents the most complete flow-based cost accounting approach in terms of the determination of resource flows, resource cost accounting intends to build the bridge to conventional cost accounting. Depending on the company’s focus, materials-only costing as well as waste material accounting represent variations for the ability of analysing separate areas more closely.

With regard to the requirements assessment, the first category aims to analyse the scientific quality of the discussed method. Thus, the first requirement of this category discusses whether flow-based cost accounting approaches directly *measure and quantify environmental aspects*. Assuming a comprehensive flow-based cost accounting system, the relevant environmental aspects are directly measured. However, the environmental aspects of the administration are not measured since the flow model focuses on production processes only. Assuming that the environmental aspects of the administration are less relevant than the environmental aspects of the production, the environmental inventory requirement is met.

The second requirement aiming to ensure scientific quality of the discussed methods concerns the ability of conducting and integrating an *environmental impact assessment*. Since flow-based cost accounting approaches consider the quantity and cost of all relevant environmental aspects, the approaches fail to provide an environmental impact assessment.

Regarding the *validity* requirement of this literature analysis, investment decisions based on flow-based cost accounting approaches lead to an improved financial and environmental performance of a company. Although environmental impact assessment is not part of flow-based cost accounting approaches, the environmental performance of a company is expected to improve, in case of an increased resource efficiency of the production system.

The *reliability* requirement ensures that the method leads to the same result when repeating the calculations under the same circumstances. The reliability can be increased with a detailed description about the application of flow-based cost accounting approaches. There are guidance documents as well as international standardisations leading to high reliability of results.

Concerning the requirements intending to ensure practical applicability, the first requirement assesses whether the method provides a sufficient degree of *comprehensibility* also to non-experts. The corresponding sub-requirements comprise an analysis of structure, complexity and language of the method. With regard to the structure, the flow models of production help to visualise and understand the overall concept as well as the underlying calculations. The language used to explain the flow-based cost accounting approaches is evaluated as concise providing sufficient degree of comprehensibility. However, the complexity of the discussed flow-based cost accounting approaches is correlated with the complexity of the production model. Hence, the associated calculations are also expected to be complex. In conclusion, the flow-based cost accounting approaches represent a ‘medium’ comprehensibility, since two of three sub-requirements are met while one is not met.

With regard to the *transparency* requirement, the corresponding sub-requirements investigate the degree of standardisation as well as the origin, quality, relevance and completeness of data. Concerning the degree of standardisation, the ISO (2012) has published the international standard 14051, which describes material flow cost accounting.

In addition, the origin and quality of underlying data depends on the installed measuring points as well as their localisation. The localisation of the measuring points recording the relevant flows of the production processes should be located with the intention to ensure the separation of the different production processes. This separation is a constant issue of debate since some processes are difficult to separate. Especially with production processes that handle multiple products, the determination of costs is a complex issue. Although the origin and quality of data can be sufficiently ensured in theory, this sub-requirement is not met due to the expected problems in practical application.

This evaluation can also be applied on the relevance and completeness sub-requirement as frequently changing production layouts and the implementation of new production processes represent a challenge which is difficult to tackle in practice. Hence, the transparency requirement is evaluated as limited (i.e. ‘medium’) transparency.

The *monetary evaluation* requirement assesses whether the result of the method can be expressed in monetary terms. Since the discussed flow-based cost accounting methods all express their results in form of costs, this requirement is met.

The table below summarises the discussion of whether flow-based cost accounting methods meet the key requirements of this thesis.

Table 15: Overview of the requirement evaluation for flow-based cost accounting methods

Goal	Requirement	Evaluation	
Scientific quality	Environmental inventory	Yes	✓
	Environmental impact assessment	No	×
	Validity	Yes	✓
	Reliability	Yes	✓
Practical applicability	Comprehensibility	Medium	O
	Transparency	Medium	O
	Monetary evaluation	Yes	✓

Source: Own representation

3.2.3. Additional methods of integrating environmental impacts

After having introduced environmental cost accounting and flow-based cost accounting methods, this subchapter deals with additional methods which cannot be classified in one of the previously described categories. While the first part discusses methods of monetising environmental impacts by internalising externalities, the second part deals with environmental indicators trying to aggregate environmental aspects and their corresponding impacts. Finally, the VDI-guideline 3800 is introduced in the third part. This approach represents a hybrid between environmental cost accounting and guidance on practical implementation regarding the integration of environmental aspects in investment decisions.

3.2.3.1. Internalisation of externalities

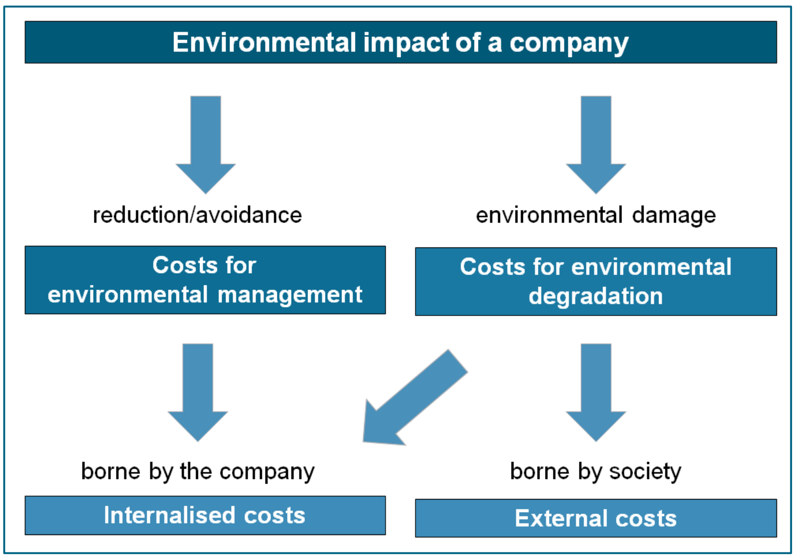
In 1987, the Brundtland Report addressed the issue of external costs (externalities) by stating that "*air and water have traditionally been regarded as 'free' goods, but the enormous costs to society of past and present pollution show that they are not free*" (Brundtland, 1987:184). The report continues to pick up the issue of exceeding nature's capacity of renewing its resources before defining externalities as costs that are "*transferred to various segments of the community in the form of damage costs to human health, property, and ecosystems*" (ibid.:184). Therefore, it is helpful to differentiate between externalities caused by manufacturing of a product or by using the product during its lifetime. In the context of this thesis, the production process is in the focus, while the utilisation phase of the product by the consumer is outside its scope.

In addition to the issue of external costs, the Brundtland Report describes three ways of how companies can internalise external costs. First, companies can invest in measures preventing environmental damage. The second option is to restore environmental damage that is seen as unavoidable result from production processes. The third option represents compensating the victims suffering from environmental degradation. (ibid.)

In this context, Prammer (2009) differentiates between ecological and economic internalisation. Regarding ecological internalisation, the intention is to avoid environmental damage which is in line with the first option described by Brundtland (1987). However, Prammer (2009) admits that also economic internalisation is included as soon as costs for avoiding environmental damage are involved. Thus, a solely economic internalisation involves an ongoing environmental damage with financial compensation (ibid.).

Figure 24 sums up the issue of externalities and the different ways for companies to internalise external costs.

Figure 24: Illustration of internalised costs and external costs



Source: According to Loew at al., 2003:40

Figure 24 describes two ways of internalising external costs. Regarding the first approach, external costs are internalised by the costs of environmental protection measures with the intention to avoid or minimise environmental impacts. This opportunity was already discussed in form of environmental cost accounting and flow-based cost accounting methods within the previous subchapters.

However, Figure 24 also reveals that not all externalities can be internalised. In this context, the German Federal Environment Ministry (FEM, 2003:39) states that "*total internalisation of external costs is impossible*" since the resulting prices for goods would be unaffordable for consumers. Klaschka (2002) also addresses the issue of monetising natural resources and identifies two unsolved problems. First, the price for natural resource resulting from monetisation would be higher than the conventional market price. Second, the methods of monetising natural resources are complex resulting from the necessity to consider parameters which are difficult to quantify. (ibid.)

Nevertheless, the FEM (2003) acknowledges that companies are forced to internalise parts of their external costs due to environmental policy in form of requirements, threshold values and bans. Nonetheless, Holliday *et al.* (2002:18) claim that "*politicians tend not to run for office on promises of making the price of goods reflect their real (higher) costs for the sake of sustainable development; consumers tend not to demand to pay such higher costs; business tends not to lobby lawmakers for higher prices*". Hence, the internalisation of externalities based on legal requirements is limited by the government, the industry and the consumers resulting in a low level of internalisation of externalities.

Yet, the European Commission and the German Federal Environment Ministry initiated a global study in 2007 with the aim of addressing the ongoing degradation of biodiversity and loss of ecosystem services. The study called 'The Economics of Ecosystems and Biodiversity' (TEEB) analyses in its fifth chapter the academic literature on methods valuing ecosystem services providing an overview of method internalising externalities (TEEB, 2010).

According to the contributing authors of this chapter, the valuation methods can be categorised into three main approaches: direct market valuation, revealed preference approaches, stated preference approaches. While the direct market valuation approach intends to internalise externalities based on market prices, revealed preference approaches observe the change in choices of individuals related to changes in ecosystems. The third category comprising stated preference approaches aim to simulate markets by conducting surveys or questionnaires in order to derive monetary values for ecosystem services. (Pascual *et al.*, 2010)

Each of the described categories contains a set of methods which are listed in the following table:

Table 16: Overview of discussed valuation methods within the TEEB study

Approach	Method
Direct market valuation	Market price-based approaches - commodity prices - market prices
	Cost-based approaches - Avoided cost method - Replacement cost method - Mitigation/restoration cost method
	Production function-based method
Revealed preference	Travel cost method
	Hedonic pricing method
Stated preference	Contingent valuation method
	Choice modelling method
	Group valuation method

Source: According to Pascual et al., 2010

In addition to the literature discussing the strengths and weaknesses of the listed valuation methods, the authors provide an analysis about the prevalence of the methods. The result reveals that contingent valuation methods are the most discussed methods in valuation literature. (Pascual *et al.*, 2010)

The literature refers to contingent valuation methods (CVM) in case of absent market prices. With the help of surveys, it is intended to either derive the respondents' willingness to pay for a particular resource or the willingness to accept a particular environmental impact. Thus, CVM aims to determine a value of a natural resource or an environmental impact by establishing a hypothetical marketplace. (Ahmed and Gotoh, 2006)

With regard to the criticism of CVM, Bebbington *et al.* (2007) emphasise the subjectivity at various points of the method. While the questions and the survey design can already point towards a subjective direction, the choice of the set of respondents can exclude respondents which are not in support of the survey. Finally, the opportunity that the respondents give biased answers leads to a lack of objectivity (ibid.).

Pascual *et al.* (2010) add the observation that the derived value from the willingness to pay diverges from the value derived from the willingness to accept to the list of criticism. Hence, the reliability of CVM is questioned. Furthermore, the authors ask whether respondents' "*hypothetical answers correspond to their behaviour if they were faced with costs in real life*" (ibid.:203).

Another popular way of valuing externalities is represented by market-based approaches. These market price-based approaches assume that the scarcity of natural resources and the environmental impact of waste and emissions are represented by its market price (Schwermer, 2007). A prominent example in this context is the EU Emissions Trading Scheme (EU ETS), which is the world's largest carbon trading scheme, or conventional market prices for heat, electricity or water (Gilbertson and Reyes, 2009).

In this context, Günther (2008) criticises that given market prices fail to represent the ecological scarcity or the environmental damage. In addition, the underlying assumption of supply and demand for building the prices does not represent any connection to environmental motives. Evidence can be seen in the current status of the EU ETS. Jasim and Kunz (2013) analyse the price development of the EU Emission Allowances at the beginning of the third trading period which is constantly below five euro per ton, instead of the originally intended 30 euro per ton.

On the one hand, this low price is caused by the allocation of too many Emission Allowances. On the other hand, the financial crisis concluded decreased production outputs. As a consequence, less CO_2 was emitted resulting in an oversupply of Emission Allowances on the market. (ibid.) Hence, no incentive is provided for investing in environmental protection measures since cost-savings remain insignificant with low market prices for Emission Allowances.

Furthermore, when comparing the production costs of electricity out of non-renewable resources with the production costs of electricity out of renewable resources, cheaper production can be achieved with electricity production out of non-renewable energy (Kost *et al.*, 2012). Thus, energy with high environmental impact can be sold at low prices reflecting the lack of internalising the cost for this environmental impact. In addition, Prammer (2009) argues that not all natural resources and environmental impacts are linked with market prices due to a lack of quantification and monetisation. Hence, the validity of this market-based approach is questionable.

Besides the valuation methods discussed in the TEEB study, an additional approach has experienced increased awareness, although not primary discussed in academic literature. In 2010, the company PUMA SE published a so-called 'environmental profit and loss account' (eP&L). The intention of the eP&L is to calculate and report the external costs caused by the operations of PUMA SE. Therefore, the environmental impacts of PUMA SE and their suppliers need to be recorded. In case of missing data (especially occurring within tier two and three of the supply chain), values were extrapolated from existing data or data retrieved from economic input-output models. These impacts were monetised in a subsequent step to finally report benefits and costs in the same format as common financial information. (Hengstmann and Seidel, 2014)

In contrast to a conventional profit and loss account, the intended aim of the eP&L can be summarised in the following four points:

- Overview and comparability of environmental impacts through monetarisation along the supply chain
- Prioritisation of environmental management activities
- Assessing the value at risk in case regulation requires increased internalisation of externalities (risk assessment)
- Positioning of PUMA SE as environmental leader within the apparel industry (ibid.)

Besides the idea to represent the result of the externality valuation in a format that managers are familiar with, the valuation technique is described only vaguely. Hengstmann and Seidel (2014) reveal only little information on the valuation technique by shortly referring to the example of valuing carbon within the eP&L. According to the authors, the fluctuation of the EU ETS-based price for carbon is too high, which leads to the necessity of determining the costs for carbon based on a literature analysis. Finally, this literature analysis reveals a median-value of 66 euro per ton CO_2. (ibid.)

Although the authors acknowledge the controversial discussion about the lacking transparency regarding the underlying valuation method used within the eP&L, Hengstmann and Seidel (2014) refer to the upcoming eP&L publications by PUMA's parent group KERING which is planned in 2016. One reason for this obvious refusal for increased disclosure might be the preservation of the first-mover advantage. However, another reason can be found in the involvement of the consulting companies TRUCOST and PWC, which are certainly interested in preventing potential future customers to calculate the eP&L on their own.

A first evidence for the latter reason is the second eP&L, which was published by Novo Nordisk in 2014, with the help of the consulting companies TRUCOST and NIRAS. Within the corresponding 32-pages publication, the authors provide transparency about every step of the eP&L methodology except the valuation method. Nevertheless, the publication reveals a high timely effort in compiling an eP&L with stating between 12 to 18 months due to the size of Novo Nordisk, its complexity and the degree of data availability. (Host-Madsen *et al.*, 2014)

It is remarkable that both companies derive the same conclusion from their eP&L, which holds that the main environmental impacts occur in tier two and three of the supply chain – those tiers in which both companies claim a low influence on the environmental management activities of the associated suppliers. (Hengstmann and Seidel, 2014; Host-Madsen *et al.*, 2014)

Due to the high attention within the business press, the eP&L method is listed within this subchapter. However, due to insufficient disclosure of the underlying valuation method leading to the amounts of external costs and benefits within the eP&L, this method cannot be part of further discussion.

3.2.3.2. Integration of environmental indicators

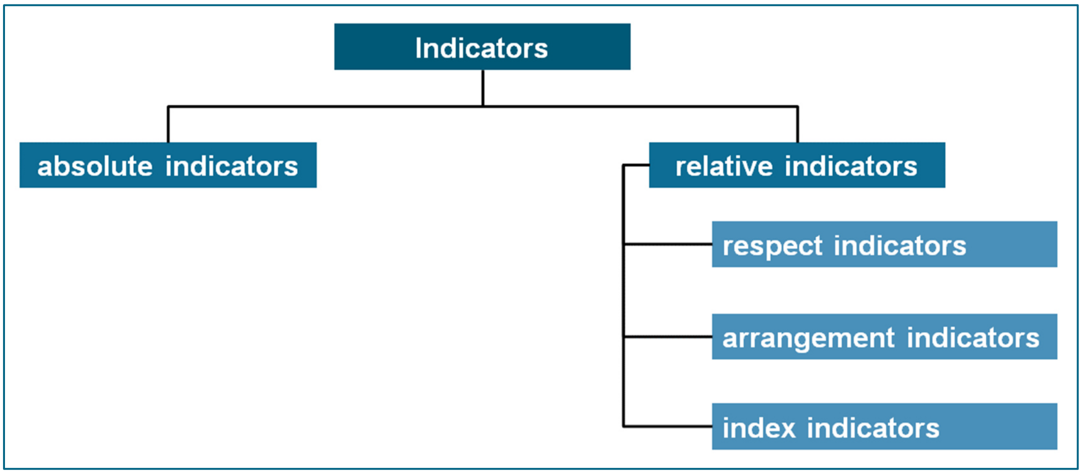
While the previous subchapter analysed approaches of internalising externalities, this subchapter discusses the literature on integrating environmental indicators in the investment appraisal. On the one hand, the intention is to quantify environmental aspects. On the other hand, the aim is to place an aggregated indicator, representing the environmental impact of the investment, next to the already established financial ratios such as PBP, ROI, NPV, etc.

The literature differentiates between two terms which are on the one hand 'environmental indicators' and on the other hand 'environmental ratios'. Gladen (2011) determines the difference between these two terms in their degree of aggregation. While indicators describe a part of reality, ratios are designed to represent a comprehensive picture of reality in an aggregated figure. Baumast (2009) states that the terms 'ratio' and 'indicator' are used interchangeably in the literature. Nevertheless, the author tries to separate these two terms by stating that the public sector or private institutions use ratios to describe the actual condition of the environment, while companies express their environmental impact in form of indicators (ibid.).

However, which of the two terms is preferably used also depends on the origin of the literature. While German authors tend to refer to ratios (compare Gladen, 2011; Baumast, 2009; Burschel 2004; Horváth, 2003), English authors tend to describe the same content with the term ‘indicators’ (compare IFAC, 2005; Dada *et al.*, 2013; Bebbington *et al.*, 2007). Since this thesis is written in English and since also German authors admit that the terms ‘ratio’ and ‘indicator’ are used interchangeably, the term ‘indicator’ will be used in the context of this thesis.

Environmental indicators are defined as figures summarising quantitative environmental data representing the environmental aspects of a company (Burschel, 2004). The goal is to measure, to quantify the environmental aspects as well as evaluating the environmental impacts of a company’s operations to establish a basis for decision-making (Dada *et al.*, 2013).

Figure 25: Different types of indicators



Source: According to Prätsch et al., 2012:273

As Figure 25 indicates, the literature on environmental indicators differentiates between absolute and relative indicators. While absolute indicators represent the quantities of environmental aspects (e.g. tons of CO_2 emitted, litres of water consumed, etc.), relative indicators set a relation between two absolute indicators (e.g. CO_2 emitted per product). In the context of environmental indicators, relative indicators mostly intend to represent the eco-efficiency of a production system. (Gladen, 2011; Baumast, 2009)

With regard to relative indicators, three main differentiations can be found in the literature. While respect indicators set the relation between two absolute figures with different bases, arrangement indicators set the relation between two absolute figures with the same bases. Thus, arrangement indicators provide information on the proportion of an absolute quantity. In addition, index indicators measure the relative variation of two absolute indicators with mostly a reference value in form of 100. (Burschel, 2004)

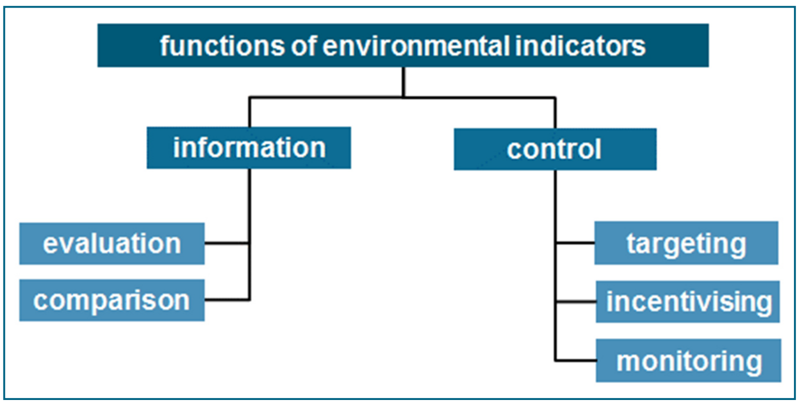
Since one indicator is not able to represent a comprehensive picture of the environmental performance of a company, Dyckhoff and Souren (2008) suggest the establishment of an indicator system. Indicator systems are defined as a sum of indicators which are set in relation to each other to inform about an actual situation. In addition, the arrangement of an indicator system depends on the issue which is intended to be represented. (Horváth, 2003) In the context of environmental indicator systems, Baumast (2009) reveals various areas of application:

- Environmental reporting or environmental balance statements
- Environmental impact assessments of production processes
- Environmental impact assessments of products
- Complementation to instruments and approaches of internal management accounting (ibid.)

Besides an informative function, indicators can also have a controlling function (see Figure 26). Hence, indicators enable an analysis about the positive or negative development of the environmental performance of a company. In case quantitative environmental goals are formulated, environmental indicators can function as a basis for environmental management accounting. (Burschel, 2004) In this context Horváth (2003) states that a comparison between intended indicator values with actual indicator values can be conducted as well as a comparison between two periods of time.

Within the aforementioned controlling function, the corresponding requirements given in the context of EMAS as well as ISO 14001 can also be satisfied by environmental indicators. These requirements comprise the representation of the actual situation in terms of a company's environmental impact as well as demonstration of the continuous environmental improvement. (Hofer and Hofer, 2012)

Figure 26: Functions of environmental indicators



Source: According to Prätsch et al., 2012:272

The literature discusses several approaches regarding environmental indicators which are suitable to represent a comprehensive picture of a company's environmental impacts as well as its continuous improvement. Posch (2012) discusses environmental indicators by clustering these into four categories.

The discussed environmental indicators and the categories can be retrieved in the following table:

Table 17: Environmental indicators and their categorisation

Category	Environmental indicator
Approximate values	Material Intensity Per Service Unit (MIPS), Cumulative Energy Demand (KEA)
Square measures	Ecological Footprint (EF), Sustainable Process Index (SPI)
Point systems	Ecological Scarcity Method, Eco-rational Path Method (EPM)
Impact-oriented indicators	Life Cycle Assessment (LCA), Eco-Indicator 99, Environmental Priority Strategies (EPS)

Source: According to Posch, 2012

In addition to these indicators, Gernuks (2005) analyses and discusses six environmental indicators, which are clustered into three different categories. The discussed indicators as well as the defined categories are displayed in the following table:

Table 18: Environmental indicators and their categorisation

Category	Environmental indicator
Impact assessment in LCA according to ISO 14040	Centrum voor Milieukunde Leiden Method (CML), UBA – impact assessment in LCA
Single-score approaches	Eco-indicator 99, Ecological Scarcity Method (ESM)
Miscellaneous approaches	ABC-Method, UBA – guideline for impact assessment of environmental aspects

Source: According to Gernuks, 2005

After discussing these six environmental indicators on the basis of six different requirements, Gernuks (2005) concludes that the Ecological Scarcity Method (ESM) is the most appropriate impact assessment method for practical implementation within an environmental management system. In this context, Posch (2012) points towards the same direction. While the author does not identify one single environmental indicator as most suitable, Posch (2012) concludes that environmental indicators within the approximate values and square measures categories do not qualify for practical implementation.

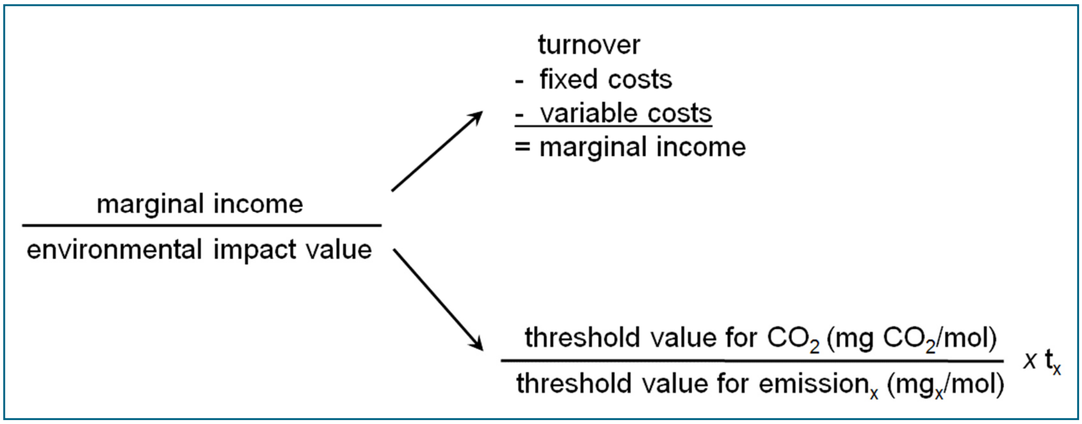
Hence, remaining indicators for further discussion are the Environmental Priority Strategies (EPS), Eco-rational Path Method (EPM), Ecological Scarcity Method as well as the concept of Environmental Impact Load (EVIL) introduced by Giegrich *et al.* (2012).

Steen (1999) introduced the concept of EPS with the intention to establish a tool in the context of product development that enables decision-makers to assess the environmental impact of given product alternatives. The method therefore aims to find a value (called Environmental Load Unit, ELU) for each significant type of resource or emission. The method comprises the use of CVM in form of determining the willingness to pay and the incorporation of uncertainty factors. The result in form of Euro per indicator unit is transformed in the ratio ELU per indicator unit, which eventually must be multiplied with the measured emission or resource consumption of a product to derive the Total Environmental Load Value. (ibid.)

While the EPS methodology, with its idea of providing an impact value that can be multiplied with emissions or resources, is similar to the Ecological Scarcity Method, the way of deriving this impact factor is questionable. The criticism focuses on the CVM which is used to derive the impact value ELU. As discussed earlier, CVM faces severe criticism regarding the subjectivity of conducting willingness to pay or willingness to accept surveys (compare subchapter 3.2.3.1.).

Another remaining indicator for further discussion is the EPM which was introduced by Schaltegger and Sturm in 1992. The method intends to measure the ecological and economic efficiency of investments in environmental protection measures. Therefore, an indicator is established measuring the relation of the marginal income (nominator) and a non-dimensional value (denominator) representing the environmental impact of an investment (see Figure 27). (Schaltegger and Sturm, 2000)

Figure 27: Composition of the EPM-indicator



Source: According to Schaltegger and Sturm, 2000

Regarding the marginal income of the investment, the expected fixed and variable costs of the investment object are deducted of its intended turnover. Concerning the non-dimensional value representing the environmental impact of an investment, a weighting factor which is normalised on basis of CO_2 is used to determine the impact assessment. The expected emissions of the investment object are multiplied with the weighting factor to derive the impact value of the denominator. The weighting factor in turn is composed of the threshold value for CO_2-emissions in relation to the threshold value of the emission under consideration. (ibid.)

Posch (2012) compares and discusses EPM and the Ecological Scarcity Method. While the author criticises the complexity of the environmental impact assessment of both methods, major criticism focuses on the EPM. First, the focus only on outputs and the emissions in air, water and soil reveal an incomplete scope of environmental impacts. Second, the lack of threshold values for emissions in soil shows that a threshold-based impact assessment soon reaches scientific limitations. (ibid.)

In addition, the economic assessment (nominator) is based on the marginal income of the investment object. Hence, the initial capital investment need is neglected. Although the focus on marginal income emphasises the running costs, the initial capital investment need is given first priority in the context of investment decisions.

Finally, the concept of EVIL-concept is discussed and compared to the Ecological Scarcity Method. Giegrich *et al.* (2012) state that the EVIL concept is similar to the basic idea behind the ESM. As with the Ecological Scarcity Method, the basic idea of the EVIL concept is to provide a non-dimensional value for the comparison of different environmental impacts. Giegrich *et al.* (2012) argue, for instance, that research revealed that the threshold value for German CO_2-equivalents per year is about 250 million tons which would prevent global temperature from exceeding a 2°C increase. Hence, 1 EVIL equals 250 million tons CO_2-equivalents. (ibid.)

However, the biggest difference to the Ecological Scarcity Method can be seen in the resource-focused view of the EVIL concept. EVILs are only available for eight resources (ibid.). Originally, the concept intends to find an aggregated indicator for resource consumption. That is why the report discusses the ability of also other indicators for being able to function as a representative aggregated indicator for resource consumption. The discussed indicators are the Cumulative Resource Demand, Cumulative Energy Demand and water consumption.

Giegrich *et al.* (2012) finally conclude that the Cumulative Energy Demand best qualifies as representative indicator for resource consumption. With this conclusion, the authors distance themselves from the EVIL concept which emphasises the weaknesses of EVIL to function as an aggregated indicator. In addition, the context of the report is written with a macro-economic perspective and not with a micro-economic perspective which would qualify for practical application in the context of a company.

As a consequence, the Ecological Scarcity Method remains as environmental indicator. On the one hand, Gernuks (2005) states that the method provides a high degree of practicability due to the aggregation to a single-score value in form of eco-points. On the other hand, Posch (2012) criticises the high degree of complexity within the underlying impact assessment which is calculated by the multiplication of emissions with eco-factors. With reference to the eco-factors, the author criticises that eco-factors are currently only available for a small number of countries. Thus, additional eco-factors are demanded to increase the validity of the eco-point indicator. (ibid.) After discussing 13 environmental indicators (see Table 19), the remaining indicator which is able to represent an aggregated figure of a company's environmental impact is the eco-point indicator based on the Ecological Scarcity Method. A detailed introduction to the Ecological Scarcity Method can be retrieved in appendix 1.

Table 19: Evaluation of environmental indicators

Environmental indicator	Evaluation		Source
Material Intensity Per Service Unit (MIPS)	×	Not applicable – no qualification for practical implementation	Posch, 2012
Cumulative Energy Demand (KEA)	×	Not applicable – no qualification for practical implementation	Posch, 2012
Ecological Footprint (EF)	×	Not applicable – no qualification for practical implementation	Posch, 2012
Sustainable Process Index (SPI)	×	Not applicable – no qualification for practical implementation	Posch, 2012
Ecological Scarcity Method (ESM)	✓	Applicable – high practicability and objectivity, however high degree of complexity	Gernuks, 2005
Eco-rational Path Method (EPM)	×	Not applicable – focus on outputs, lack of threshold values for soil emissions, ignores capital investment need	Posch, 2012
Eco-Indicator 99	×	Not applicable – lacking transparency of original impact assessment causing low acceptance for decision-makers	Gernuks, 2005
Environmental Priority Strategies (EPS)	×	Not applicable – monetisation via CVM implies uncertainty and risk for subjectivity	Bebbington *et al.*, 2007
Centrum voor Milieukunde Leiden Method (CML)	×	Not applicable – missing weighting and aggregation of the resulting environmental impact assessment	Gernuks, 2005
UBA – impact assessment in LCA	×	Not applicable – subjectivity in ranking the impact assessment results via a verbal-argumentative approach	Gernuks, 2005
ABC-Method	×	Not applicable – subjectivity due to verbal argumentation of environmental impacts	Gernuks, 2005
UBA – guideline for impact assessment of environmental aspects	×	Not applicable – high timely effort, practicability and reliability	Gernuks, 2005
Environmental Impact Load (EVIL)	×	Not applicable – authors already suggest different indicator, focus only on eight resources	Giegrich *et al.*, 2012

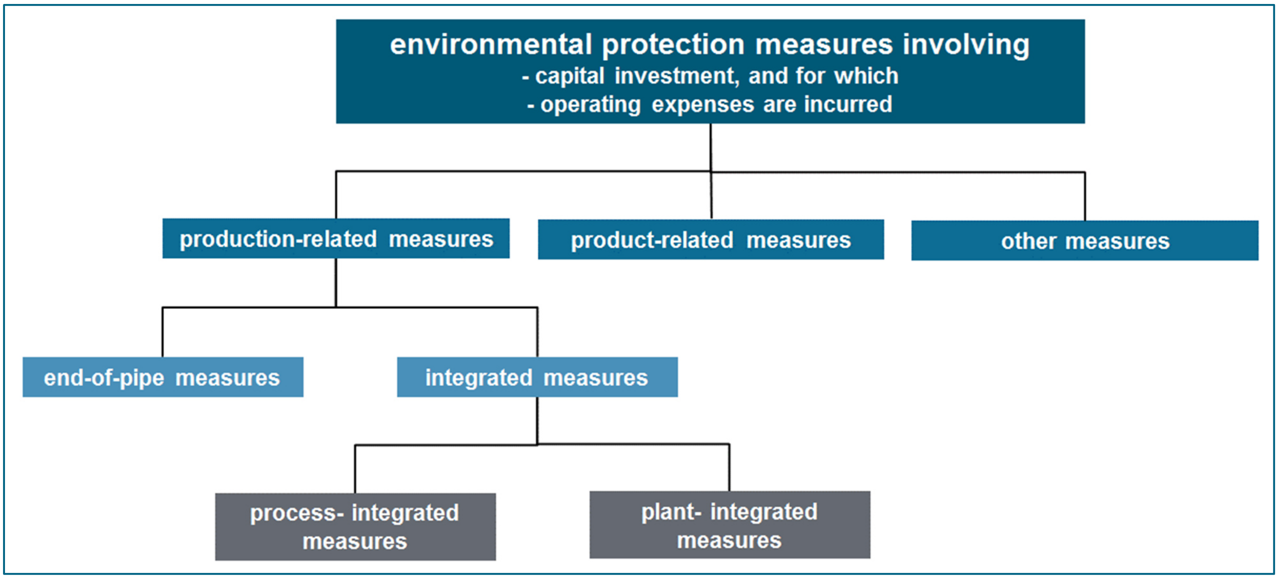
Source: Own representation

3.2.3.3. VDI-guideline 3800

In December 2001, the Association of German Engineers (VDI) published an updated version of the guideline 3800 focusing on the determination of costs for environmental protection measures. This guideline intends to assist in the determination of environmental costs with an ex-ante and ex-post view. As a consequence, the guideline is separated into three parts. While the first part deals with the underlying problem of delimitating environmental costs and the different forms of environmental protection, the second part provides guidance for the ex-post determination of incurred environmental costs. The third part deals with the ex-ante view on expected environmental costs and refers to an investment appraisal scenario. (VDI, 2001)

While the second part of the VDI-guideline 3800 further differentiates between product-related, production-related and miscellaneous environmental costs, the focus in the context of this thesis is on production-related costs (see Figure 28).

Figure 28: Categorisation of industrial environmental protection measures in VDI-guideline 3800



Source: According to VDI, 2001:8

The guideline intends to serve as a basis for internal and external reporting and for comparing companies, their operations as well as their plants and facilities in terms of environmental protection measures. In addition, the aim is to provide the basis for decision-making through an environmentally-adjusted investment appraisal. However, the guideline assumes the underlying intention that "*business investment decisions […] are mainly concerned with realizing the most cost-effective means of fulfilling specific environmental protection regulations*" (VDI, 2001:17). Hence, the focus is set on effectively achieving compliance with environmental regulation rather than resource efficiency or even environmental performance improvement.

Concerning the second part of the guideline, the determination of environmental costs starts with the delimitation from external costs. Hence, the guideline states that "*external costs that arise from the company's commercial activities and which cannot be allocated to the company in form of prices, taxes, duty or some similar mechanism are not considered*" (ibid.:6).

The VDI (2001) continues its guidance for determination by separating environmental costs between either capital expenses, due to an investment in environmental protection measures, or by operating expenses, due to constant operation of the environmental protection measures. This differentiation helps to separate environmental costs from the environmental protection measure. Therefore, both types of environmental costs (capital and operating expenses) are independent from the type of environmental protection measure (e.g. end-of-pipe, process-integrated, plant-integrated).

After delimiting environmental costs from external costs and from the type of environmental protection measure, the VDI (2001:5) defines costs as "*costs for those measures […] which aim to reduce, avoid or eliminate as well as monitor and document the environmental impact that arises […] from the company's activitie*s". While previously introduced definitions focus on the different cost-types and the allocation of indirect environmental costs, this definition sets the relation between cause and effect in the centre of attention. Hence, the guideline focuses on the relation between costs and improving the environmental performance of a company.

As mentioned above, the VDI (2001) further differentiates between capital expenses and operating expenses for determining environmental costs. With regard to capital expenses, the acquisition value of the environmental protection measure needs to be booked under fixed assets in the property, plant and equipment section. However, the guideline differentiates between end-of-pipe measures and integrated measures. While end-of-pipe measures are fully booked, the guideline suggests determining the environmental protection proportion of integrated measures via a convention of the users of the same integrated measure within the same industry. (ibid.)

Nevertheless, this suggestion is criticised by Loew *et al.* (2003) since comparable integrated measures are hard to determine due to differing circumstances between companies. In addition, the open exchange about integrated environmental protection measures would reveal vital production information which is generally not intended by companies.

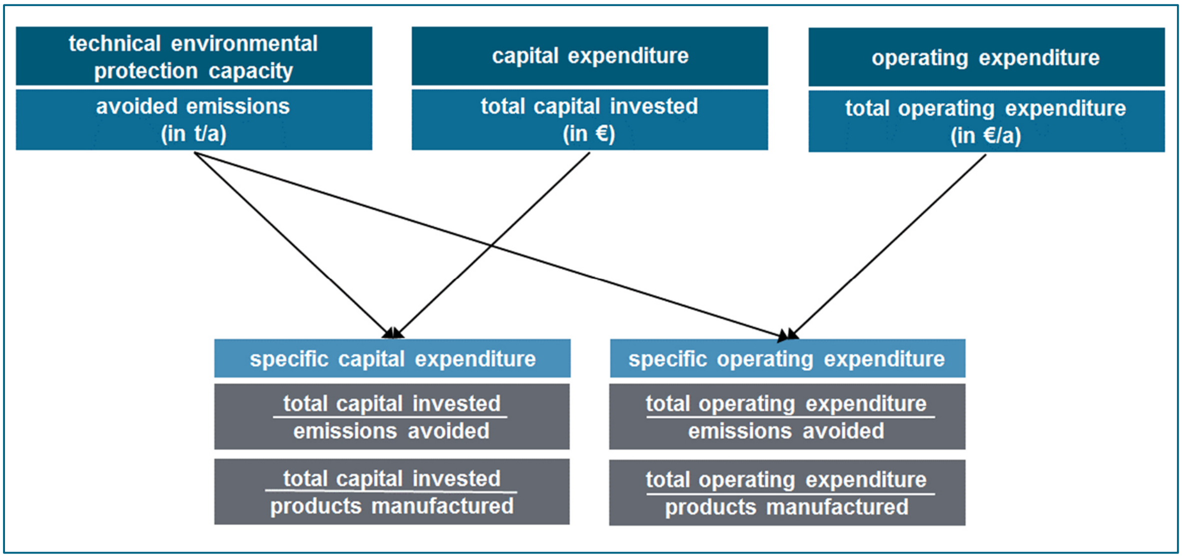
Regarding the operating expenses of environmental protection measures, the VDI (2001:14) defines these as "*the value of all goods consumed by the company and all services provided to the company for the purposes of environmental protection*". In addition, the guideline suggests to start determining environmental operating expenses which are already incurred by the regular accounting system. Examples for those operating expenses are expenses for auxiliary and operating materials, energy, maintenance, repair, environmental levies, fees as well as expenses for monitoring systems. (ibid.) Finally, the VDI (2001:15) suggests to "*set up individual cost-centres for end-of-pipe systems*" which is in line with the environmental cost accounting methods introduced in the previous subchapters.

Concerning the third part of the guideline, the ex-ante determination of environmental costs focuses on the implementation in the investment decision. As in the previous part of the guideline, the determination of environmental costs is separated into capital expenses and operating expenses. While the determination within the second part focuses on the costs which are incurred by the regular accounting system, the third part of the guideline provides suggestions for the ex-ante determination of environmental costs.

For instance, with regard to the capital expenses of end-of-pipe measures "*the capital outlay […] comprises all expenditures until implementation*" (ibid.:18). However, the guideline lacks in providing a suggestion on valuing capital expenses for integrated environmental protection measures. Concerning the ex-ante determination of operating expenses for environmental protection measures, the VDI (2001) suggests summing up the transfer prices of technical materials and supplies consumed. This assumes that the consumption of materials and supplies of an environmental protection measure is known in advance and that transfer prices are given.

Finally, the VDI (2001) intends to build indicators functioning as a basis of evaluating the financial effort of compliance with environmental regulation. These indicators are subdivided into two categories – capital expenses and operating expenses. Hence, two indicators are suggested per category: on the one hand, the financial effort per product and on the other hand the financial effort per avoided emission. (ibid.) Figure 29 illustrates the suggested indicators with their original data:

Figure 29: Suggested indicators in the VDI-guideline 3800



Source: According to VDI, 2001:25

These four indicators are intended to be placed next to the already established financial indicators evaluating the advantageousness of an investment (e.g. PBP, ROI, NPV, IRR, etc.). However, assuming that not all eight indicators point towards the same direction, the assembled set of indicators complicates the basis for the decision-maker. In this case, the indicators work against the original intention, which is to simplify complex realities to enable the decision-maker to invest in the investment object with the highest relative advantageousness.

On the one hand, the provision of four indicators, which are divided into evaluating the efficiency of capital expenditure and operating expenditure, helps the decision-maker to evaluate not only the one-time costs (i.e. capital expenditure) but also the regular costs (i.e. operating expenditure). This enables the decision-maker to exclude investment objects with low capital expenditure but high operating expenditure or vice versa.

Nevertheless, to reduce complexity, the set of additional indicators should be reduced to two indicators – one indicator focusing on capital expenditure and one indicator emphasising operating expenditure. This reduction can be achieved by focusing on only one item for the denominator which is either products or avoided emissions.

In case, the avoided emission is chosen as preferred denominator, CO_2-equivalents would qualify as denominator as this would include not only one type of emission. Yet, other emissions would be excluded, representing a remaining weakness to the approach presented by the VDI.

Another weakness is the ex-ante determination of material and supplies based on transfer prices, since prices of material and supplies do necessarily correlate with their environmental impact. In case no transfer price is available for a material or supply, the baseline assumption would be that also no environmental impact is caused, which holds not to be true.

This in turn leads to the baseline problem which is also criticised by Loew *et al.* (2003). The authors state that the focus on determining environmental costs and relating them to the amount of avoided emissions or manufactured products only indirectly leads to an improved environmental performance. In addition, Loew *et al.* (2003) criticise the focus on achieving compliance with environmental regulations instead of establishing a system that enforces continuous improvement.

Nevertheless, the VDI-guideline 3800 represents a practical approach towards the issue of determining environmental costs and environmental investments. The structure, separating capital expenditure from operating expenditure, ex-ante determination from ex-post determination as well as end-of-pipe measures from integrated measures, helps to understand and manage the issue of environmental costs and investments. However, the remaining issue of delimitating environmental costs in the context of integrated environmental protection measures could not be solved sufficiently.

3.2.3.4. Evaluation of additional methods of integrating environmental impacts

Internalisation of externalities

While a voluntary internalisation via higher product prices is regarded as unrealistic, the discussion determines only a soft internalisation via environmental legislation due to lobby pressure from politicians, industry and consumers. The global TEEB study discusses several methods trying to value ecosystem services to derive a value of external costs. In addition, the study reveals that CVM are most referred to in literature in absence of market prices. Yet, major criticism focuses on the subjectivity of the research design as well as on the risks of receiving biased answers from respondents.

With regard to market-based prices for resources and emissions, the example of the price development of the Emission Allowances within the EU ETS provides evidence, that market prices do not reflect the environmental impact but rather the relationship between supply and demand of the traded Emission Allowances.

When discussing the internalisation of externalities according to the *environmental inventory* requirement, it is obvious that not all environmental aspects are tracked. The example of the EU ETS shows that Emission Allowances comprise CO_2 emissions as well as CO_2-equivalents of Nitrous oxide (N_2O) and Perfluorocarbons (PFCs). Nevertheless, the additional climate damaging emissions, such as amongst others volatile organic compounds (VOC), are not included (European Commission, 2013). Therefore, the environmental inventory requirement is partly met since the relevant environmental aspects are tracked.

In addition, the methods of internalising externalities do not comprise an *environmental impact assessment*. Especially, in case of market prices (or in case of CVM intending to create a fictitious market) the amount of costs does not imply any information about the environmental impact.

The internalisation of externalities via market prices or through environmental legislation results in higher costs to the company. Hence, the management is interested in decreasing these costs. On the one hand, this can be achieved via avoiding these costs through lobbying. On the other hand, the management might implement measures to increase the resource efficiency of production.

In this case, the method's *validity* would be emphasised as financial and environmental performance would increase. However, since additional costs through internalisation of externalities remain low, the bigger incentive is seen in lobbying against such internalisation rather than increasing the resource efficiency of production. Therefore, the validity of the method is questionable leading to the evaluation that this requirement is not met.

With regard to the *reliability* of the methods of internalisation of externalities, the requirement assesses whether the method's calculations produce the same result after repetition. In this context, the reliability is given for market-based approaches. In case of the EU ETS, the price for an Emission Allowance is determined by supply and demand. However, the market prices are not calculated by management and thus are outside the scope of the reliability assessment.

In case of absent market prices, CVM is conducted to determine fictitious market prices. The reliability of CVM is questionable due to the dependence of the respondents' answers to the willingness to pay or willingness to accept surveys. As it is unlikely that two persons, examining these surveys separately, end up with the same result, the reliability requirement is not met.

Regarding the intended practical applicability of the method, the requirement concerning *comprehensibility* assesses the structure, degree of complexity and language of the discussed methods. While the EU ETS follows a clear and logical structure of valuing the market prices for Emission Allowances according to supply and demand, the structure of CVM cannot be guaranteed to be logical as it depends on the user to determine the structure.

The same evaluation applies to the degree of complexity sub-requirement. Although buying and selling of Emission Allowances within the EU ETS follows a clear and logical structure, the determination of fictitious market prices with CVM is highly complex. Nevertheless, both approaches make use of concise and understandable language. As a consequence, the requirement regarding comprehensibility is partly met.

The second requirement, aiming to ensure practical applicability, focuses on *transparency* of the discussed methods. This requirement is composed of three sub-requirements assessing the relevance and completeness, the origin and quality of data as well as the degree of standardisation. Regarding relevance and completeness of data, the market prices for electricity, heat, water and Emission Allowances already cover a number of environmental aspects. In addition, CVM aims to determine fictitious market prices in case of absent real market prices. Hence, this sub-requirement is met.

Concerning the origin and quality of market prices, the underlying calculations of market prices for electricity, heat or water as well as EU ETS Emission Allowances are not transparent for the interested public. On the other hand, CVM are conducted by the users themselves enabling sufficient traceability of the data origin and ensuring a sufficient degree of quality. Since CVM is only applied in case of absent market prices, the origin of the majority of data (i.e. real market prices) cannot be traced back. Therefore, the sub-requirement assessing the origin and quality of methods for the internalisation of externalities is evaluated as not met. The third sub-requirement addresses the degree of standardisation. As there is no standard on determining market prices, regardless of real or fictitious prices, this sub-requirement is not met. As all three sub-requirements are not met, the requirement regarding the method's transparency is not met.

Finally, the last requirement regarding *monetary evaluation* assesses the ability of expressing the results in monetary terms. Since both methods determine market prices, this requirement is met.

The summary and discussion of the analysed methods for the internalisation of externalities can be retrieved in the following table:

Table 20: Overview of the requirement evaluation for internalisation of externalities

Goal	Requirement	Evaluation	
Scientific quality	Environmental inventory	Partly	O
	Environmental impact assessment	No	×
	Validity	No	×
	Reliability	No	×
Practical applicability	Comprehensibility	Medium	O
	Transparency	Low	×
	Monetary evaluation	Yes	✓

Source: Own representation

Integration of environmental indicators

The goal of the integration of environmental indicators is to position an additional indicator next to the already established indicators within the investment appraisal. Hence, environmental indicators intend to quantify environmental aspects and provide an aggregated figure for the current status of environmental impacts of a company.

While the literature describes the advantages and weaknesses of relative and absolute indicators, the analysis reveals that no single indicator is able to provide an aggregated picture. Hence, environmental indicator systems are suggested, which can be disaggregated in form of a pyramid. Besides an informative function, the literature discusses the controlling function of environmental indicators, which are able to monitor either the historic development or the development against pre-defined targets.

Finally, over 13 environmental indicators are identified and discussed (see Table 19) resulting in the eco-points indicator being most suitable to represent the environmental impacts of a company due to the strengths of the underlying Ecological Scarcity Method. Hence, the following paragraphs discuss if the Ecological Scarcity Method meets the key requirements of this thesis.

Regarding the *environmental inventory* of the eco-points indicator, the Ecological Scarcity Method comprises the most relevant environmental aspects by equally focusing on inputs and outputs. In addition, it is up to the user to determine the scope of application and measurement. Since there are eco-factors developed for a wide range of environmental aspects, the environmental inventory requirement is met.

The second requirement assessing the scientific quality of environmental indicators is the ability to conduct an *environmental impact assessment*. With the multiplication of the resource and emission flows with the corresponding eco-factors, the environmental impact assessment is already integrated within the resulting eco-points indicator. Hence, this requirement is met.

With regard to the *validity*, the requirement assesses whether the investment decision, based on environmental indicators, lead to an improved financial and environmental performance of the company. Concerning the Ecological Scarcity Method, the amount of eco-points already incorporates an informative function. In addition, the opportunity of conducting a controlling function is given as well since the indicator can also be disaggregated either on basis of several sub-units or on basis of several environmental aspects. Due to the informative and controlling functions, the eco-points indicator provides the opportunity of leading to an improved environmental performance.

Assuming that financial performance data originating from the investment appraisal method can be complemented by environmental performance data, the validity requirement is regarded as being met.

The eco-factors are calculated from external institutes. Hence, the *reliability* requirement is met since the user only needs to multiply the amount of resources and emissions with the given eco-factors to derive the eco-points.

The *comprehensibility* requirement intends to ensure practical applicability. This requirement is composed of three sub-requirements analysing the structure, the degree of complexity and the conciseness of language. The Ecological Scarcity Method follows a clear and logical structure through the multiplication of eco-factors with resource and emission flows. Hence, this sub-requirement is met.

However, major criticism focuses on the complexity of the eco-factor calculation which is conducted by external institutes to ensure their objectivity. Although the user does not have to calculate the eco-factor, the complexity of the underlying calculations result in decreased acceptance, since users have to struggle to comprehensively understand the Ecological Scarcity Method. Hence, this sub-requirement is not met since the increased complexity within the eco-factor calculation does not support the comprehensibility of the method.

The language, explaining the Ecological Scarcity Method, uses analogies to already established financial accounting vocabulary. Since this analogy ensures concise explanation, this sub-requirement is met. Due to the fact that two of three sub-requirements are met, the requirements assessment results in a limited (i.e. medium) comprehensibility.

As with the comprehensibility requirement, the *transparency* requirement is composed of three sub-requirements addressing the relevance and completeness of data, the origin and quality of data as well as the degree of standardisation. Regarding the relevance and completeness of data, criticism in terms of practical applicability concentrates on the fact that there are eco-factors for only a small number of countries. Nevertheless, for these countries in which eco-factors are available, the most relevant environmental aspects are dealt with. However, the missing eco-factors for the majority of countries lead to the evaluation of not meeting this sub-requirement.

The eco-factor is also in the centre of criticism regarding the origin and quality of the underlying data. The publications refer to various sources for the determination of eco-factors. Yet, the discussion about the choice of sources keeps an ongoing issue in literature. Hence, this sub-requirement is not met sufficiently.

Regarding the third sub-requirement of the transparency requirement, the degree of standardisation is assessed. Detailed guidelines on the application of the Method of Ecological Scarcity are publicly available. Thus, this sub-requirement is met. Nevertheless, as a consequence of two sub-requirements not being met, the transparency requirement is evaluated with ‘medium’ transparency.

The Ecological Scarcity Method fails to meet the requirement of *monetary evaluation* since the dimensional unit is expressed in eco-factors instead of monetary terms. This lack of monetary evaluation decreases the acceptance by management and therefore, the monetary evaluation requirement is not met.

The table below summarises the requirement assessment with their corresponding evaluations for environmental indicators:

Table 21: Overview of the requirement evaluation for environmental indicators

Goal	Requirement	Evaluation	
Scientific quality	Environmental inventory	Yes	✓
	Environmental impact assessment	Yes	✓
	Validity	Yes	✓
	Reliability	Yes	✓
Practical applicability	Comprehensibility	Medium	O
	Transparency	Medium	O
	Monetary evaluation	No	×

Source: Own representation

VDI-Guideline 3800

The VDI-guideline 3800, which was updated in 2001, intends to provide guidance on the determination of costs for environmental protection measures. The guideline helps to separate capital expenditure from operating expenditure as well as the type of environmental protection measure (i.e. end-of-pipe or integrated environmental protection). Furthermore, the provided definition of environmental costs aims to set the relation of costs and improved environmental performance of a company. Besides these helpful suggestions, the proposed approach of delimitation of environmental costs for integrated environmental protection measures is criticised and regarded as being neither scientific nor practical.

In addition, the guideline advises four indicators to assess the financial and environmental performance of the investment in an environmental protection measure. These suggested indicators can be divided into two indicators setting the relation of capital expenses with environmental performance and two indicators setting the relation of operating expenses with the environmental performance of an investment object. While the nominator is either capital or operating expenditure, the denominator comprises the amount of either avoided emissions or manufactured products. Regarding the amount of avoided emissions within the denominator, major criticism focuses on the difficulty of finding a representative type of emission. Moreover, the suggestion of adding four indicators to the already established financial indicators within the investment appraisal is critically discussed, since the amount of information complicates the investment decision.

With regard to the *environmental inventory* requirement, the VDI-guideline 3800 directly measures and quantifies the most relevant environmental aspects. However, the suggested indicators relate the amount of avoided emissions in the denominator with the operating or capital expenditure in the nominator. Since only one environmental aspect or a representative environmental aspect (i.e. CO_2-equivalents) can be implemented in the indicator, the environmental inventory requirement is partly met.

The second requirement intending to ensure scientific quality assesses whether the method conducts an *environmental impact assessment*. The VDI-guideline 3800 focuses on the determination of environmental costs. In addition, the suggested indicators imply the relation between costs and avoided emissions. Since the amount of costs and avoided emissions does not comprise an environmental impact assessment, this requirement is not met.

The *validity* requirement analyses whether investment decisions based on the suggested indicators of the VDI-guideline 3800 lead to an improved financial and environmental performance. With the focus on increasing the resource efficiency by figuring out the optimal balance between environmental performance and financial performance of an investment, the guideline's validity requirement is met.

While the definition of environmental costs offers minor room for interpretation, the *reliability* of the guideline and the nature of the guideline itself, ensure that two persons conducting an investment appraisal under the same conditions should derive the same result.

With the intention to ensure practical applicability, the *comprehensibility* requirement is composed of the sub-requirements assessing the structure, degree of complexity and used language of the method. The major strengths of the VDI-guideline 3800 can be seen in the clear and logical structure. In addition, the technical terms are precisely defined. However, the complexity especially regarding the unsolved problem of delimitating environmental costs remains a limiting issue. Hence, the comprehensibility requirement is partly met and the degree of comprehensibility is evaluated as being ‘medium’.

With regard to the *transparency* requirement, the corresponding sub-requirements analyse the relevance and completeness of data, the origin and quality of data as well as their degree of standardisation.

Concerning the relevance and completeness of data, the part within the guidelines addressing the environmental costs suggests recording all relevant environmental aspects. Nevertheless, the suggested indicators comprise only one relevant environmental aspect. Hence, this sub-requirement is partly met. Regarding the origin and quality of data, environmental costs comprise all costs that are already tracked. Hence, the origin can be traced back. Furthermore, the precise definitions on technical terms ensure a sufficient quality of recorded data. Thus, this sub-requirement is met. Since the degree of standardisation can be evaluated as high due to the nature of a guideline, this sub-requirement is met. In conclusion, two of three sub-requirements are met, which results in medium transparency of the VDI-guideline 3800.

Regarding the requirement of *monetary evaluation*, the proposed indicators combining the amount of avoided emissions with capital or operational expenditure provide the basis for management acceptance.

Hence, the summary of the requirements assessment in the context of the VDI-guideline 3800 can be expressed in the following table:

Table 22: Overview of the requirement evaluation for VDI-Guideline 3800

Goal	Requirement	Evaluation	
Scientific quality	Environmental inventory	Partly	O
	Environmental impact assessment	No	×
	Validity	Yes	✓
	Reliability	Yes	✓
Practical applicability	Comprehensibility	Medium	O
	Transparency	Medium	O
	Monetary evaluation	Yes	✓

Source: Own representation

3.2.4. Summary and discussion of the method screening and evaluation

Summary

The result of the deficit analysis within the previous chapter reveals the weaknesses of current environmental-oriented investment appraisal methods. In addition, several reasons for these weaknesses are identified, providing a first set of requirements, which new methods need to meet in order to increase the chance of successful practical application. Together with literature regarding environmental performance measurement a set of requirements is composed providing the answer to the first two sub-research questions:

Which requirements does the integrated method need to meet in order to ensure a sufficient degree of scientific quality?

Which requirements does the integrated method need to meet in order to ensure its practical applicability?

Besides the identification and definition of requirements ensuring sufficient scientific quality and practical applicability, the evaluation parameters are determined to guarantee a standardised evaluation procedure.

The requirements regarding the method's validity and reliability have to be emphasised as key requirements. The method which is regarded as best suitable, either for direct application or for further development, at least needs to fulfil these two requirements.

The results of the method analysis is summarised in the following table:

Table 23: Results of the method analysis according to the given requirements

Requirement	Environ-mental Cost Accounting	Flow-based Cost Accounting	Internali-sation of externalities	Environ-mental indicators	VDI-guideline 3800
Environmental inventory	×	✓	○	✓	○
Environmental impact assessment	×	×	×	✓	×
Validity*	×	✓	×	✓	✓
Reliability*	×	✓	×	✓	✓
Comprehen-sibility	○	○	○	○	○
Transparency	○	○	×	○	○
Monetary evaluation	✓	✓	✓	×	✓

*Source: Own representation - *key requirement*

Discussion

Concerning *environmental cost accounting methods*, the validity requirement is not met since an increase or decrease in environmental costs does not correlate with the environmental performance of a company. Due to the unsolved problems regarding the allocation of indirect costs as well as the delimitation of environmental costs for integrated environmental protection measures, the method's reliability is questionable as well. Moreover, these unsolved problems leave room for interpretation leading to limited transparency of environmental cost accounting approaches. Since all requirements ensuring scientific quality are negatively evaluated, environmental cost accounting approaches can also be excluded from further discussion.

Flow-based cost accounting methods aim to increase the resource efficiency of a company. The precise measurement and quantification of relevant environmental aspects along the production processes positively affects the environmental inventory requirement. However, connection to the production flow model implies a high degree of complexity limiting the comprehensibility and transparency requirement. Nevertheless, the validity of flow-based cost accounting is given through its focus on resource efficiency even though no environmental impact assessment is conducted. Hence, flow-based cost accounting approaches qualify for further discussion.

The literature describes several ways of *internalisation of externalities*. Since the most developed approach is the integration via market prices, this type of integration is subject of evaluation. The environmental inventory requirement is partly met since there is not a market price available for every natural resource or emission. In the context of the EU ETS, the traded Emission Allowances do not comprise all relevant emissions (only CO_2 emissions and the CO_2-equivalents of N_2O and PFCs). In addition, the basic problem, that market prices do not reflect the environmental impact of the resource or emission, remains unsolved. Furthermore, the vast criticism on the execution of CVM to determine fictitious market prices is responsible for negative evaluations regarding reliability and transparency requirements. On the basis of these weaknesses, methods internalising externalities are excluded from further research in this context.

The integration of *environmental indicators* comprises the advantage that suitable indicators can be placed next to the already established financial indicators within an investment appraisal. In addition, environmental indicators are the only one offering the opportunity of an environmental impact assessment. After the analysis of 13 environmental indicators, the eco-points indicator based on the Ecological Scarcity Method is identified as most appropriate for further discussion. While the requirements assessment predominantly revealed positive results, monetary evaluation is not possible with the eco-points indicator. In addition, the transparency and comprehensibility requirements are limited due to the complex calculation behind the eco-factor calculation. Although this method does not score positive results regarding all requirements, the overall result qualifies for further research.

Finally, the *VDI-guideline 3800* intends to provide an orientation on the determination of environmental costs and assessment of investments in environmental protection measures. While the guideline provides assistance in form of clear definitions and separation of various types of environmental protection measures as well as capital and operating expenses, the guideline lacks to provide an environmental impact assessment. Nevertheless, the suggested indicators provide a monetary evaluation in combination with a quantification of environmental aspects. Thus, the method's validity ensures that decision-making comprises a balance between financial and environmental aspects. Finally, this subchapter intends to provide an answer to the third sub-research question:

How well do additional methods from environmental management and management accounting systems meet the requirements to qualify as a basis for the development of the integrated investing method?

After discussing the results of the methods assessment, two main conclusions can be drawn. First, no single approach is able to meet all seven requirements and therefore directly qualifies as method for practical application. On the one hand, this conclusion appears to be logical since the deficit analysis of the previous chapter reveals that no environmental investment appraisal method has developed as common business standard so far. On the other hand, this conclusion emphasises the need for developing a new integrated investing method. Second, flow-based cost accounting, environmental indicators as well as the VDI-guideline 3800 show sufficient potential for further development, due to their positive evaluation in the key requirements validity and reliability.

Therefore, an additional sub-research question needs to be formulated with the intention to be answered within the following subchapter:

<u>Sub-research question 3a:</u>
How to combine these three methods to develop an integrated investing method which is able to meet all seven requirements ensuring sufficient scientific quality and practical applicability?

3.3. Method derivation

The previous subchapter identifies three approaches that are suitable to function as a basis for developing an integrated investing method. Moreover, an additional sub-research question is formulated. Hence, this subchapter aims to provide an answer to the question of how to combine the three identified methods to develop an integrated investing method that is able to meet all seven requirements. This subchapter is organised along the seven requirements and represents a detailed analysis of the three remaining approaches and its implications for the development of the integrated investing method.

3.3.1. Environmental inventory

The original question regarding the environmental inventory requirement is formulated as follows:

Are all relevant environmental aspects directly measured and quantified?

The table below represents the evaluation results of the best three approaches which are discussed in the previous chapter:

Table 24: Result of the environmental inventory requirement evaluation of the best three methods

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
✓ The most relevant environmental aspects are directly measured but not from indirect areas such as administration.	✓ ESM comprises most relevant environmental aspects with its focus on input and output flows. There are eco-factors developed for a wide range of environmental aspects.	O The suggested indicators relate the amount of avoided emissions in the denominator with the operating or capital expenditure in the nominator. However, only one environmental aspect or a representative environmental aspect (i.e. CO_2-equivalents) can be implemented in the indicator.

Source: Own representation

The strength of flow-based cost accounting approaches is their focus on inputs and outputs of the production model. An additional strength is the flow model which links the input and output flows to the production system. Hence, the environmental aspects can directly be tracked in a way that reflects the layout of the given production system. However, flow-based cost accounting approaches fail to take into consideration the environmental aspects of indirect areas such as administration. Therefore, not all relevant environmental aspects are directly measured and quantified.

The VDI-guideline 3800 suggests indicators relating avoided emissions to operating or capital expenses. Although, all relevant environmental aspects are directly measured or quantified, the VDI-guideline 3800 is able to consider only one (representative) type of environmental aspect at a time. Nevertheless, the suggested indicator is useful in representing the relation between environmental aspects and financial aspects.

The ESM is able to take into consideration a wide range of environmental aspects. The resulting eco-points indicator is derived by the multiplication of input and output flows with the associated eco-factors. In a concluding step, the eco-points of several environmental aspects can be summed up to an aggregated single-score indicator.

However, the range of considered environmental aspects is limited to the available eco-factors since they are customised to the specific country of consideration. This set of country-specific eco-factors is limited. The ESM refers to this problem with the opportunity of calculating eco-factors for other countries ‘from a Swiss perspective’.

Another limitation addresses the considered scope of environmental aspects. In this context, Frischknecht and Büsser Knöpfel (2013) refer to the relevance of environmental aspects by stating that the scope of available country-specific eco-factors depends on available environmental goals of the corresponding government. Yet, the issue about assessing the relevance of environmental aspects depends on the specific process under consideration at first. The following step aims at allocating eco-factors to the considered relevant environmental aspects.

Implications for the development of the integrated investing method

With regard to the development of an integrated investing method, the environmental inventory requirement assesses whether all relevant environmental aspects are measured and quantified. The strength of the ESM is its ability of recording all relevant environmental aspects and transferring them to the unit of eco-points. The underlying multiplication of eco-factors with input and output flows can be linked to the flow model of the flow-based cost accounting approaches. Hence, the flow model of a production system functions as a basis for the considered environmental aspects enabling a relation to production reality. Nevertheless, the environmental aspects of the non-production areas should also be taken into consideration to derive a comprehensive basis of analysis in case these environmental aspects show significant relevance.

3.3.2. Environmental impact assessment

The question regarding the environmental impact assessment requirement is formulated as follows:

Is the method able to assess the environmental impacts of the relevant environmental aspects?

The table below represents the evaluation results of the best three approaches which are discussed in the previous chapter:

Table 25: Result of the environmental impact assessment requirement evaluation of the best three methods

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
✗ No impact assessment available.	✓ With the multiplication of the resource and emission flows with a weighted eco-factor, the environmental impact assessment is already integrated within the eco-points indicator.	✗ Focus is on the determination of environmental costs. Indicators imply the relation between costs and avoided emissions. Hence, no environmental impact assessment is examined.

Source: Own representation

Flow-based cost accounting approaches focus on identifying, allocating and monitoring costs on the basis of a flow model reflecting the layout of production. In general, the height of costs does not reveal any conclusion about the environmental impact. Hence no environmental impact assessment is conducted within flow-based cost accounting approaches.

Similarly, the VDI-guideline 3800 focuses on allocating and delimitating environmental costs. As with flow-based cost accounting approaches, costs do not provide any information about the environmental impact. However, the VDI-guideline 3800 relates operating or capital costs to avoided emissions in order to present the interconnectedness of environmental and financial aspects. Nevertheless, no environmental impact assessment of relevant environmental aspects is conducted within the VDI-guideline 3800.

In contrast to these two approaches, the environmental indicator in form of eco-points already implies an environmental impact assessment. The ESM intends to multiply resource and emission flows with corresponding eco-factors. The actual environmental impact assessment is represented by the eco-factor which relates actual resource or emission flows with their corresponding critical flows.

Implications for the development of the integrated investing method

Thus, regarding the development of the integrated investing method, the only option to implement an environmental impact assessment is to refer to the eco-points indicator since the two other approaches do not comprise an environmental impact assessment.

3.3.3. Validity

The question regarding the validity requirement is originally formulated as follows:

Does the decision based on the integrated investment method lead to an improved financial and environmental performance of the company?

The table below represents the evaluation results of the best three approaches which are discussed in the previous chapter:

Table 26: Result of the validity requirement evaluation of the best three methods

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
✓ The environmental and financial performance of a company is expected to improve, due to an increased resource efficiency of the production system.	✓ Due to the informative and controlling functions, the eco-points indicator provides the opportunity of leading to an improved financial and environmental performance.	✓ Focus is on increasing the resource efficiency by figuring out the optimal balance between environmental performance and financial performance of an investment.

Source: Own representation

Flow-based cost accounting approaches focus on increasing resource efficiency by identifying and eliminating waste as result for inefficient production processes. Although no environmental impact assessment is carried out, the validity requirement is met due to the focus on increasing efficiency, which assumes and increases in environmental performance and financial performance. However, it is difficult to plan and control environmental and financial performance based on flow-based cost accounting due to the absence of the environmental impact assessment.

The validity of the ESM is met as well due to the informative and controlling function of the eco-points indicator. Nevertheless, the eco-points indicator only focuses on environmental impacts and thus only provides information regarding the environmental performance. Hence, it is necessary to add financial information in order to relate these to the already provided environmental information so that environmental and financial performance can be assessed.

The VDI-guideline 3800 is able to eliminate this weakness since it suggests a ratio relating environmental aspects to financial aspects. In this context, VDI-guideline 3800 is similar to flow-based cost accounting approaches regarding its focus on increasing resource efficiency, by figuring out optimal balance between environmental performance and financial performance.

Implications for the development of the integrated investing method

With regard to developing the integrated investing method, it is obvious that environmental impact data needs to be related to corresponding financial data. In addition, environmental and financial performances need to be planned and controlled requiring a direct cause-and-effect relationship, which is generally not provided by flow-based cost accounting methods. Therefore, the weakness of the eco-points indicator regarding the missing link to financial performance can be overcome by a combination with the VDI-guideline 3800. Thus, the integrated investing method intends to set the relation between environmental impact data in form of the eco-points indicator to financial data. In order to conduct an informative and controlling function of this ratio, it is necessary that strategic environmental and financial performance goals are provided.

3.3.4. Reliability

The question regarding the reliability requirement is formulated as follows:

Does the method lead to the same result when repeating its underlying calculations?

The table below represents the evaluation results of the best three approaches which are discussed in the previous chapter:

Table 27: Result of the reliability requirement evaluation of the best three methods

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
✓ Guidance documents as well as international standardisations are available, leading to high reliability of results.	✓ The eco-factors are calculated by external institutes. Hence, the reliability requirement is met since the user only needs to multiply the amount of resources and emissions with the given eco-factors to derive the eco-points.	✓ The very nature of the guideline itself ensures that two persons conducting an investment appraisal under the same conditions should derive the same result.

Source: Own representation

Regarding the flow-based cost accounting approaches, an international standard by the ISO on material flow cost accounting as well as several guidance documents ensure reliability, in general. However, the standard aims at application in various types of businesses. Hence, the standard comprises rather broad formulations providing room for interpretation and thus the possibility of deviating results.

The VDI-guideline 3800 is similar to flow-based cost accounting approaches. The very nature of the guideline ensures general reliability. While the guidance on delimiting environmental costs is formulated broadly and therefore offers room for deviation, the suggested calculations regarding investment appraisal methods are more concretely formulated.

With regard to the underlying calculations of ESM, the method offers the most concrete formulation and thus produces highly reliable results. The eco-factors are already composed by external independent institutes necessitating the practitioner only to multiply resource and emission flows with corresponding eco-factors in order to calculate the amount of eco-points. Assuming that there is a standardised way of measuring and monitoring resource and emission flows, the ESM provides the highest reliability of the three discussed approaches.

Implications for the development of the integrated investing method

Concerning the development of the integrated investing method, all three approaches meet the reliability requirement. Nevertheless, flow-based cost accounting approaches are neglected due to broad formulations offering room for interpretation and deviating results. Furthermore, the ESM provides the highest reliability followed by the concrete proposals of the VDI-guideline 3800 regarding the calculations of investment appraisal methods. Hence, a combination of these two approaches ensures that the integrated investing method leads to the same results when repeating the underlying calculations.

3.3.5. Comprehensibility

The question regarding the comprehensibility requirement is formulated as follows:

Does the method provide a sufficient degree of comprehensibility also to non-experts?

In the context of defining comprehensibility, this requirement is composed of three sub-requirements, discussing the structure, complexity of the approaches as well as the language used to explain them. The table below represents the evaluation results of the best three approaches which are discussed in the previous chapter:

Table 28: Result of the comprehensibility requirement evaluation of the best three methods

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
✓✓✗ = ○ Structure: ✓ Flow models of production help to visualise and understand the overall concept as well as the underlying calculations. Language: ✓ Concise language providing sufficient degree of comprehensibility.	✓✓✗ = ○ Structure: ✓ The Ecological Scarcity Method follows a clear and logical structure through the multiplication of eco-factors with resource and emission flows. Language: ✓ ESM uses analogies to already established financial accounting vocabulary.	✓✓✗ = ○ Structure: ✓ The major strength of the VDI-guideline 3800 can be seen in the clear and logical structure. Language: ✓ The technical terms are precisely defined.

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
Complexity: × Correlation with the complexity of the production model. Hence, the associated calculations are also expected to be complex.	Complexity: × The increased complexity within the eco-factor calculation does not support the comprehensibility of the method.	Complexity: × The complex problem of delimiting environmental costs remains an unsolved issue.

Source: Own representation

The flow model within flow-based cost accounting approaches enables a structured representation providing detailed insights into production-related environmental aspects and their associated costs. Moreover, the use of concise language results in a sufficient degree of comprehensibility. However, the limiting factor is the complexity of the production model and the corresponding flow model resulting in a medium comprehensibility of flow-based cost accounting approaches.

The structure of the ESM contains a three-step procedure. While the first step identifies and measures environmental aspects, these aspects are allocated to the corresponding eco-factors in the second step. The third step contains the calculation of the eco-points which can be derived by multiplying environmental aspects with the eco-factors. Hence, the structure of ESM is plain and easy to comprehend. Furthermore, the language used to explain the ESM uses analogies to already established management accounting vocabulary. Nevertheless, the complexity within the eco-factor calculation might decrease acceptance since it requires in-depth expert knowledge. Hence, the ESM is evaluated with limited comprehensibility.

Similarly to the two discussed approaches, the VDI-guideline 3800 is also evaluated with a limited degree of complexity. The clear structure, especially regarding the differentiation of various types of expenses and investments, helps to comprehend the approach. The comprehensibility is supported by the language using technical terms which are precisely explained in a glossary. However, the high complexity regarding the unsolved problem of delimitating environmental costs limits the total degree of comprehensibility of the VDI-guideline 3800.

Implications for the development of the integrated investing method

Concerning the development of the integrated investing method, all discussed methods generally show a limited degree of comprehensibility. Yet, besides their weaknesses, limiting the degree of complexity, each approach also contains certain strengths. Hence, the integrated investing method has to comprise a combination of the strengths of the three discussed methods.

Regarding the sub-requirement structure, the flow model ensures realistic representation of environmental aspects and thus provides detailed insights. This flow model can be combined with the three-step procedure of the ESM. Hence, within the step of measuring environmental aspects, the resource and emission flows can directly be located within the flow model.

The VDI-guideline 3800 and the ESM represent a useful combination with regard to the sub-requirement of language used. While the VDI-guideline 3800 precisely defines terms in a glossary, the ESM uses analogies with conventional accounting language which ensures optimal comprehensibility.

Unlike the other two sub-requirements of comprehensibility, the complexity sub-requirement does not reveal any strength for the three discussed approaches. While the complexity of the production model prevents comprehensibility concerning flow-based cost accounting approaches, the unsolved problem of delimiting environmental costs is a complex issue within the VDI-guideline 3800.

The complexity problem within the ESM is located within the calculations of the eco-factors. Based on the fact that the eco-factors are calculated by independent external institutes, the question occurs whether it is necessary to understand the details of the underlying calculations of the eco-factor. The eco-points indicator can be calculated even if the underlying calculations of the eco-factors are not comprehended by non-experts. In this case, it is a matter of trust in the quality and professionalism of the external independent institute calculating the eco-factors. Hence, of all three approaches, the ESM provides a weakness, which can be overcome in case the practitioner has sufficient trust in the underlying calculations of eco-factors.

3.3.6. Transparency

The question regarding the transparency requirement is formulated as follows:

Does the method provide a sufficient degree of transparency?

In the context of defining transparency, this requirement is composed of three sub-requirements, discussing the relevance and completeness of data, their origin and quality as well as the degree of standardisation of the approaches.

The table below represents the evaluation results of the best three approaches which are discussed in the previous chapter:

Table 29: Result of the transparency requirement evaluation of the best three methods

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
○○✓= ○	××✓ = ○	×✓✓ = ○
<u>Relevance & completeness:</u> ○ Frequently changing production layouts and the implementation of new production processes represent a challenge which is difficult to tackle in practice.	<u>Relevance & completeness:</u> × Missing eco-factors for the majority of countries restrict the utility of the ESM.	<u>Relevance & completeness:</u> × The part within the guidelines addressing the environmental costs suggests recording all relevant environmental aspects. However, the suggested indicators comprise only one relevant environmental aspect.

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
Origin & quality: O Data depend on the installed measuring points and their localisation. However, the separation of the different production processes represents a constant issue.	Origin & quality: × Criticism refers to various sources for the determination of eco-factors. The discussion about the choice of sources keeps an ongoing issue in literature.	Origin & quality: ✓ Regarding the origin and quality of data, environmental costs comprise all costs that are already tracked. Hence, the origin can be traced back.
Degree of standardisation: ✓ The ISO (2012) has published the international standard 14051 which describes material flow cost accounting.	Degree of standardisation:✓ Detailed guidelines on the application of the ESM are publicly available.	Degree of standardisation: ✓ Furthermore, the precise definitions on technical terms ensure a sufficient quality of recorded data.

Source: Own representation

Flow-based cost accounting approaches provide the problem with frequently changing production layouts requiring huge effort to keep the corresponding flow models up-to-date. In addition, tracing back the origin of data as well as assessing their level of quality heavily depends on the localisation of installed measuring points. While the sub-requirements relevance and completeness of data as well as origin und quality of data limit the transparency of flow-based cost accounting approaches, the degree of standardisation supports the transparency by the existence of an ISO standard.

Although sufficient data on resource and emission flows are assumed to be available, the limited availability of corresponding country-specific eco-factors restricts the transparency of the ESM. In addition, the discussion about the derivation of eco-factors criticises the choice of the underlying sources for actual flows and critical flows and thus keeps an ongoing debate. Nevertheless, sufficient degree of standardisation is provided by detailed guidelines about the application of ESM. Hence, the ESM is evaluated with a limited transparency.

The VDI-guideline 3800 reveals a discrepancy regarding the relevance and completeness of data. While all environmental costs, including costs of all relevant environmental aspects, are recorded, the suggested indicators only comprise one type of environmental aspect. Although the most relevant environmental aspect can be chosen to be part of the ratio, the lack of completeness of data remains. The origin of costs can be traced back since environmental costs are already tracked by the accounting system. In addition, the precise definitions of technical terms within the glossary ensure a sufficient degree of standardisation.

Implications for the development of the integrated investing method

As with the comprehensibility requirement, the three approaches provide limited overall transparency due to their weaknesses. However, certain weaknesses of one approach can be overcome by strengths of the remaining approaches.

Concerning the sub-requirement relevance and completeness of data, all three approaches show limitations due to their weaknesses. With regard to the frequently changing production layouts, a standardised method needs to be developed ensuring that changes in the production layout immediately are represented in the flow model as well. The effort for this constant adaptation depends on the one hand on the complexity of the production as well as on the frequency of changes to production on the other hand.

Concerning the missing eco-factors for several countries, the expected results of a recently started research initiative, which intends developing eco-factors for European and non-European countries, provides a possible solution in future (Damme, 2014). So far, the possible gap of country-specific eco-factors needs to be overcome by calculating ‘from a Swiss perspective’. The limiting factor that all environmental costs are recorded by the accounting system but only one representative environmental aspect is part of the ratio, can be resolved by a combination with the ESM. Hence, the environmental impacts of all relevant environmental aspects are part of the ratio proposed within the VDI-guideline 3800.

The sub-requirements of tracing back the origin and assessing the quality of data can be met by combining the strengths of all three approaches. Concerning environmental costs, the VDI-guideline 3800 includes all costs that are tracked by the accounting system and thus provides traceability to their origin. Regarding environmental impacts, the ESM is able to determine the impacts of the corresponding environmental aspects. Nevertheless, the localisation of the environmental impacts within the flow model requires on the one hand an up-to-date flow model and on the other hand a clear delimitation of production processes. Both requirements are expected to be an ongoing issue in business practice. Another limiting factor is the discussion about the determination of the right original data in order to calculate correct eco-factors. However, this discussion must be addressed by the external independent institute and not by the practitioner of the ESM using the eco-factors to calculate the environmental impact in form of eco-points.

Concerning the degree of standardisation, all three methods offer a sufficiently high degree of standardisation in form of ISO-standards, guidelines or guidance documents. Hence, the integrated investing method requires a precise guidance offering less room for manipulation and leads to comparable, reproducible results of high quality.

3.3.7. Monetary evaluation

The question regarding the monetary evaluation requirement is formulated as follows:

Does the method express its result in monetary terms?

The table below represents the evaluation results of the best three approaches which are discussed in the previous chapter:

Table 30: Result of the monetary evaluation requirement evaluation of the best three methods

Flow-based cost accounting	Environmental indicators	VDI-guideline 3800
✓ Express results in form of costs.	× The dimensional unit is expressed in eco-factors instead of monetary terms.	✓ The proposed indicators combining the amount of avoided emissions with capital or operational expenses provide the basis for management acceptance.

Source: Own representation

While flow-based cost accounting approaches express the results in costs and thus in form of monetary terms, the VDI-guideline 3800 complements cost data with data on corresponding environmental aspects. The only approach failing the expression of results in monetary terms is the ESM which expresses the results in the unit of eco-points.

Implications for the development of the integrated investing method

Therefore, the integrated investing method prefers the approach of the VDI-guideline 3800 combining monetary values with environmental aspects. Since no environmental impacts are part within this ratio, the eco-points indicator can substitute the environmental aspect data to ensure the representation of environmental impacts as well.

3.3.8. Summary of the method derivation

The previous subchapters intend to answer the sub-research question (3a) of how to combine the best three approaches to develop an integrated investing method that is able to meet all seven requirements. The analysis reveals that all three approaches are part of the following description of the integrated investing method since each approach is able to overcome the weaknesses of the other approaches.

However, their influence depends on the discussed requirements which is visualised within the following table.

Table 31: Summary of requirements assessment of the best three approaches

Requirement	Flow-based Cost accounting	Environmental Indicators	VDI-guideline 3800
Environmental inventory	✓	✓	O
Environmental impact assessment	×	✓	×
Validity	✓	✓	✓
Reliability	✓	✓	✓
Comprehensibility	✓✓× = O	✓✓× = O	✓✓× = O
Transparency	OO✓= O	××✓ = O	×✓✓ = O
Monetary evaluation	✓	×	✓

Source: Own representation

3.4. Summary and discussion of the method development

Summary

Prior to the method development chapter, the deficit analysis identified reasons for the failure of current methods which mainly lack practical applicability. Hence, the first part of the method development chapter picks up this issue and determines general requirements for a successful practical application of a method. In addition, a short literature review contributes additional requirements regarding a sufficient degree of scientific quality. As a result, the first part reveals a list of seven requirements with corresponding evaluation parameters aiming to ensure a standardised evaluation procedure.

The second part of the method development chapter identifies methods from a literature review which might comprise a basis for further method development. Hence, these methods are discussed along the seven requirements. The result of this requirements assessment is listed in Table 23 and reveals that there is no single method which meets all seven requirements. Nonetheless, there are three approaches that qualify for further analysis. These three approaches comprise the flow-based cost accounting approach, environmental indicators in form of the eco-points indicator as well as the VDI-guideline 3800.

The third part of the method development chapter comprises the method derivation in which the three remaining approaches are discussed in detail. This discussion according to the seven requirements aims to identify the strengths and weaknesses of each approach as well as the implications for the integrated investing method. The analysis reveals that all three approaches are part of the subsequent description of the integrated investing method since each approach is able to overcome the weaknesses of the other approaches (see Table 31).

Discussion

There are certain limitations involved in the method development process concerning the choice of requirements, the evaluation parameters as well as the choice of analysed approaches. With regard to the requirements, one part originates from the deficit analysis. Depending on the structure, scope and detail of this deficit analysis, the resulting requirements might have been different to the requirements used in the context of this dissertation. The same argumentation addresses the resulting additional requirements of the short literature review.

As a consequence, seven requirements serving two aims which are either to ensure practical applicability on the one hand or to ensure sufficient scientific quality on the other hand evolved. In case, these two aims are equally weighted, the concluding requirements assessment lack comprising weighting factors, so that the resulting evaluation of the assessed approaches is equally balanced between these two aims. Furthermore, the underlying evaluation comprises two parameters assessing whether the discussed approach meets the requirement or not. However, three requirements comprise an additional parameter which allows the option of partly meeting the requirements. Strictly seen, this procedure is not completely consistent, representing another limitation within the method development chapter.

Finally, an additional limitation within the method development chapter addresses the choice of the analysed methods, since there is no prior determination of the scope regarding the choice of methods. Hence, criticism might involve the claim of including additional methods in the requirements assessment. Nevertheless, the scope of discussed methods is already set broadly, containing cost accounting methods, for instance. Another indicator for a sufficiently broad selection of methods is the final evaluation of the methods. Table 23 reveals that some methods score negative results for most of the requirements. Thus, a saturated amount of suitable methods is taken into consideration within the method development chapter.

4. Method description

4. Method description

The following subchapters aim to provide an answer to the main research question by describing the new developed method that is able to integrate financial and environmental data in the investment process of companies to achieve strategic environmental and financial goals. Furthermore, this chapter is structured along the phases of the conventional investment processes in companies.

4.1. Defining a strategic environmental goal

Assuming that companies have already strategic financial goals in place, strategic environmental goals need to be defined in analogy to financial goals. This definition is important since the integrated investing method aims to support the achievement of these strategic goals. Hence, the investment decision is always bound to the question of how far the investment object is going to move the company closer to achieving its strategic environmental and financial goals.

While there might be strategic environmental goals regarding the products of a company, this thesis focuses on the strategic goals related to the production and its facilities. Hence, the environmental performance of the operations is in the focus of a definition. The ISO 14031 (2000:5) defines environmental performance as the "*results of an organization's management of its environmental aspects*". Furthermore, environmental performance evaluation is described as the process of measuring the progress of the environmental performance achieving the environmental goals (ibid.). Therefore, strategic environmental goals should aim for a continuous improvement of environmental performance.

This continuous improvement in environmental performance can be achieved by either defining qualitative factors (e.g. the organisation of an environmental management system and its successful certification) or quantitative factors (e.g. decrease of a set of relevant environmental aspects by a given amount). In analogy to the definition and control of strategic financial goals, it is necessary to translate qualitative factors into quantitative figures so that the decision-maker can quantify the degree of strategy support within the investment decision. For instance, the qualitative environmental goal of being the leader in an external environmental ranking by a specific year can be translated into quantitative facts by determining KPIs describing which aspects to adjust in production operations in order to achieve this qualitative environmental goal.

With regard to quantitative environmental goals, companies tend to express these goals by a set of relevant environmental aspects. These environmental aspects in form of resource and emission flows need to be precisely defined to establish a common understanding across various parts of the company. This precise definition should also comprise the scope of measurement as well as reporting intervals and responsibilities for data validity.

In order to improve the environmental performance of a company, the strategic goals aim to reduce the defined set of environmental aspects, mostly by a certain amount which is either expressed in a percentage or as absolute or relative figures. In addition, this reduction goal is augmented with a target year until the targeted amount of environmental aspects should be reached. This in turn, requires a base year in which the total amount of environmental aspects is recorded representing the starting point of the strategy.

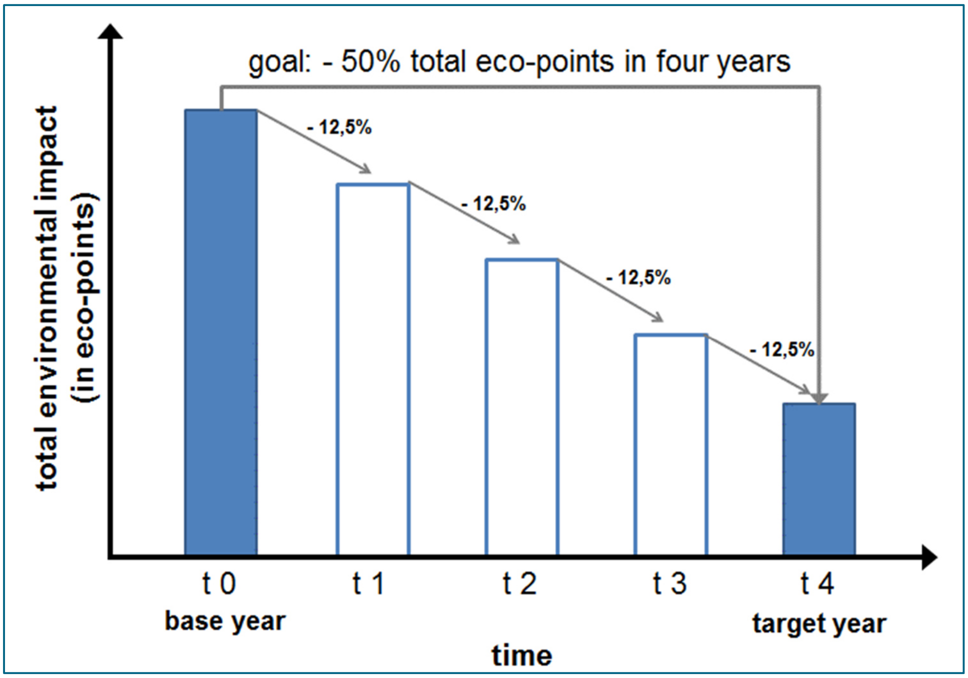
In order to monitor and control the achievement of the environmental goals, a shared environmental information system is necessary, which is based on the reported data that is measured on a standardised basis. Besides the comparison of actual environmental performance with the targeted environmental performance, this shared information system should also contain information on investment projects and other organisational measures, which have a significant impact on the environmental performance. Their impact on the strategic goals as well as their status on implementation need to be tracked in order share the information with other decision-makers to function as knowledge exchange platform. In addition, the information about current investment projects helps to provide forecasts on the future development of environmental performance.

Implications for the integrated investing method

The integrated investing method intends to determine the environmental impacts of the relevant environmental aspects. Hence, the strategic environmental goal should also address the environmental impact of a company. In the context of quantifying the environmental impacts, the ESM can be applied and environmental goals can be expressed in a targeted amount of eco-points. This expression in form of the eco-points indicator takes the environmental impacts of a company into consideration and thus supports the effort of decreasing these impacts. In addition, the aggregation to a single indicator, reflecting the environmental impacts, supports corporate environmental performance management.

Regarding the determination of a target value of eco-points, which the company should achieve by a certain target year, the total eco-points of a base year need to be calculated first. Hence, all relevant aspects of the defined base year are measured and multiplied by its corresponding eco-factors in order to determine the amount of total eco-points of the base year. Depending on the strategic management of the company, the concluding step involves either a benchmark with the strategic environmental goals of competitors or the consultation with stakeholders or additional internal or external experts. Based on this process, a target amount of eco-points and a target year in which this amount should be achieved is determined. This aggregated target value can be broken down to formulate a target amount of eco-points for each year between the base year and the target year (see Figure 30). Depending on the size and structure of the company, those annual targeted reduction goals can be allocated to the business units, divisions or investment centres. As a consequence, these target values can be integrated in the investment appraisal step of single investments which is described later on.

Figure 30: Definition of strategic environmental goals with derivation of annual target values

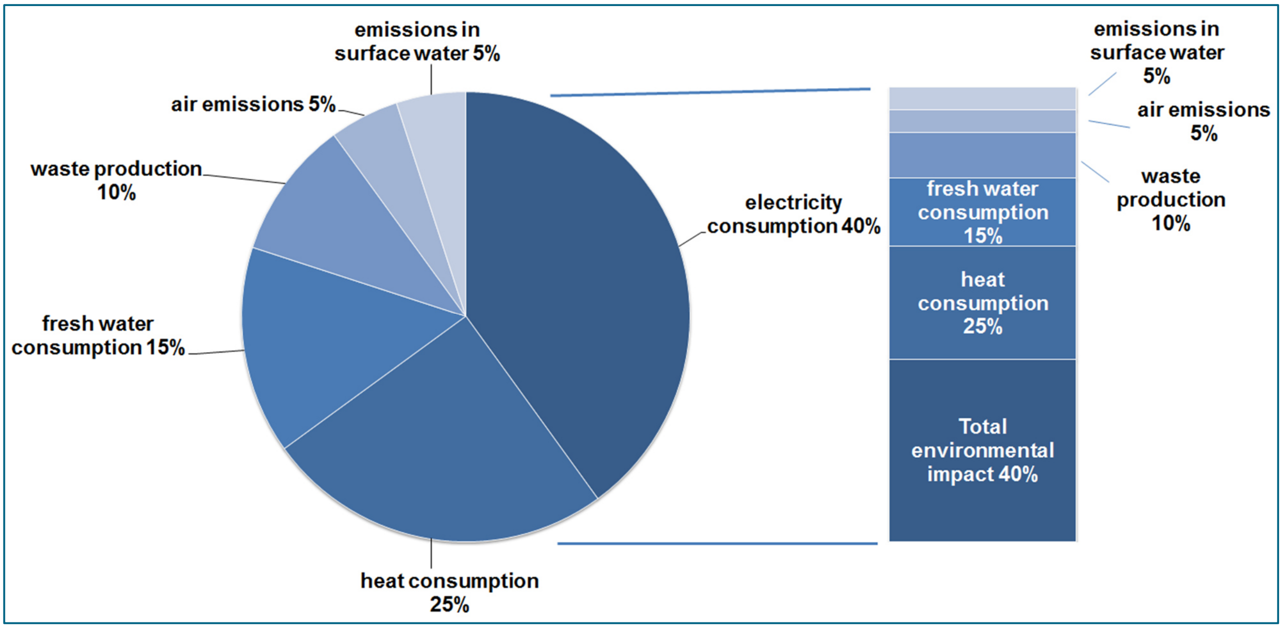


Source: Own illustration

However, besides the total amount of eco-points, the corresponding proportions are an important detail which should not be neglected. In this context, Gernuks (2005) describes a method how to derive environmental goals in the context of the continuous improvement process of environmental management systems, which is based on the basis of the ESM. The author claims that the biggest proportion of the total eco-points highlights the environmental aspect on which environmental management measures should concentrate in order to improve environmental performance (ibid.).

This aspect should also be part of the monitoring process of environmental goals to avoid that total eco-points decrease on the one hand while environmental impacts shift, for instance, from energy consumption to fresh water consumption on the other hand. Therefore, the integrated investing method suggests expressing the proportions of total eco-points in pie charts to ensure a balanced reduction across the various environmental impacts.

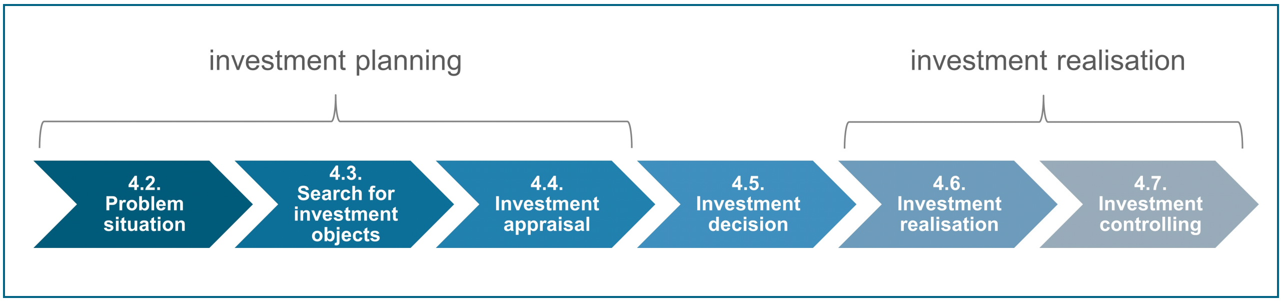
Figure 31: Example for proportions of environmental aspects on total environmental impact of a company



Source: Own illustration

The following subchapters, describing the new integrated investment method, are structured according to the common investment process in companies as illustrated within the following figure:

Figure 32: Phases of an investment process



Source: Own illustration, according to Prätsch et al., 2012; Poggensee, 2011

4.2. Problem situation

The first phase of the investment process contains a detailed description of the problem situation in form of a problem statement. As a consequence, first considerations sketch possible solutions to the formulated problem. These considerations might analyse whether or not there are organisational solutions to the formulated problem, making an investment obsolete. In case an investment is unavoidable, first considerations might discuss whether purchasing equipment or adjusting the production process represents a feasible solution.

Furthermore, the question about who formulates the problem statement and the underlying motives for the investment is addressed in this phase. On the one hand, top management might identify an investment need due to external forces such as the strategy of competitors. On the other hand internal analyses by the management can point towards the need for investing such as the conclusion that a business-as-usual-scenario will not support the company in achieving its strategic financial goals. Besides these top-down view regarding investment motives, the need for investments can also be formulated from a bottom-up perspective. In this case the operating personnel identify adjustment to machinery or production processes and hand in ideas for increasing production efficiency.

Depending on the formulation of the problem, the type of investment can be determined in this phase as well. While greenfield investments aim for building new production capacities, brownfield investments focus on investing in existing property plant and equipment. This might comprise renovating old machinery, replacing them with new equipment or rationalisation investments aiming for increased efficiency in production operations.

In addition, a precise description of the problem situation also implies setting the scope of consideration. For instance, in case the problem situation reveals a replacement of an old machine, its functions, performance data, its corresponding resource and emission flows as well as delimitation in form of a detailed description of what is considered to be part of the machine is determined in this phase. This detailed description serves as a basis to find adequate investment alternatives within the following step.

Besides the detailed description of the actual problem situation, this phase also comprises the description of the ideal situation which is intended to be achieved by the investment. In addition, a feasible deadline is formulated determining the date by which the investment has achieved the targeted ideal situation. Furthermore, a rough time plan representing the milestones in form of the project steps as described within the following subchapters are part of this phase.

Implications for the integrated investing method

The integrated investing method also modifies the problem situation phase of the investment process. Hence, the necessity of reducing environmental impacts due to stricter environmental legislation and resulting threshold values can also represent a reason for a brownfield investment. Furthermore, the environmental management department can be a trigger for investments by the analysis that business as usual will not support the company in achieving its strategic environmental goals. In addition, the environmental management department’s main task is to ensure continuous improvement of corporate environmental performance. In case, organisational measures are exhausted investing in environmentally friendly technology (i.e. best available technology) is unavoidable. As a conclusion, the description of the problem situation also needs to comprise an environmental perspective besides the already existing financial perspective.

Besides the determination of the problem and the formulation of the investment need, it is important to describe the current situation and the desired future situation. Both situations can be depicted based on flow models helping to visualise the problem situation as well as the desired solution. When describing the ideal situation at the end of this investment phase, the targeted reduction of environmental impacts also needs to be included in case of brownfield investments. Whereas in case of greenfield investments, the ideal situation should include the goal of keeping the increase of environmental impacts as low as possible.

Finally, the following information should also be entered into the shared environmental information system by the responsible planner:

- Name and ID of investment project
- Name of responsible planner
- Status (e.g. ‘problem identified’)
- Description of the current situation
    - Functions and performance data
    - Resource and emission flows
    - Delimitation
- Description of the ideal situation
    - Target functions and performance data
    - Target resource and emission flows
    - Delimitation
- Time plan with project phases and corresponding deadlines

4.3. Search for investment objects

The second phase involves the search for investment objects that are necessary to provide a solution to the problem situation which is formulated in the previous phase. On the one hand, the solution might comprise listing investment objects from various suppliers that are able to directly replace the existing machinery or equipment. On the other hand, a solution might involve an alternative design of production processes in case alternatives are feasible or the current state of the art proposes such an alternative design.

For each investment alternative, the associated expenditures need to be recorded. Besides the expenditure to acquire the investment object, the considered costs might comprise costs for transporting the investment object to its final destination as well as costs for installation the investment object within the production system. The third type of costs is associated with the operational costs of the investment alternative. These comprise amongst others, the costs for media consumption such as materials, energy, water or other resources, costs for personnel, maintenance or wastes associated with the operation of the investment alternative. Finally, the financial costs need to be projected comprising depreciation, loan payment rates or interest payments.

Implications for the integrated investment method

Besides a detailed record of costs associated with each investment alternative, the corresponding environmental aspects need to be recorded. This necessitates requesting resource- and emission-flow-related data from the supplier. While this request demands the supplier's ability to quantify and measure material and resource flows, the most relevant environmental aspects need to be defined beforehand. The responsible planner has the duty to perform a validity check of the resource and emission flows provided by the supplying company.

The concluding step intends projecting the environmental impact by multiplying the environmental aspects with its corresponding eco-factors so that an amount of eco-points can be calculated for each investment alternative.

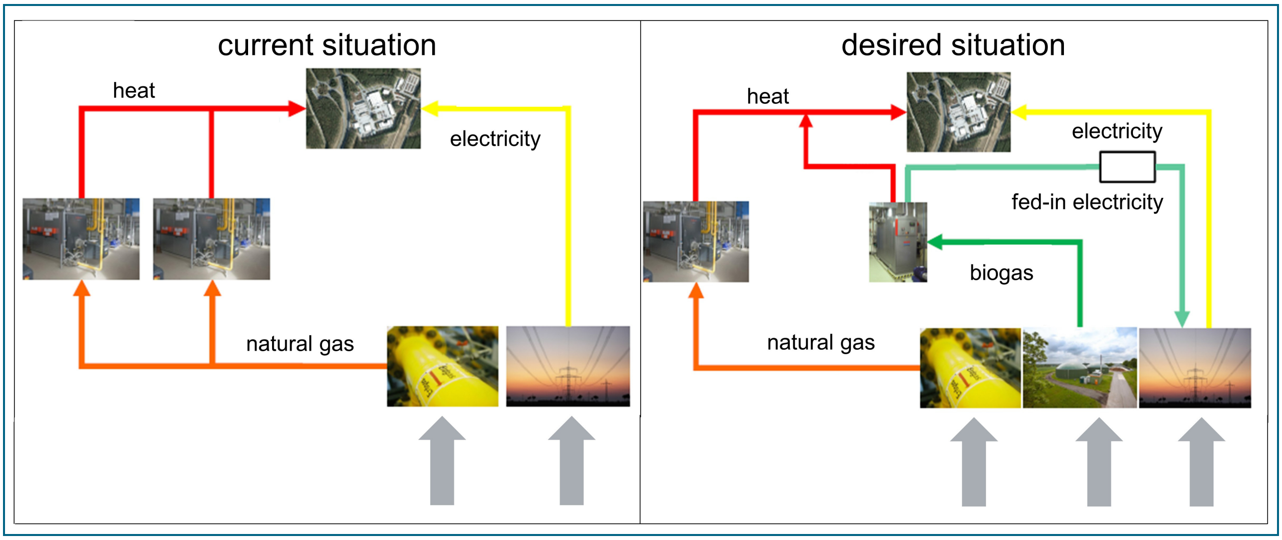
Another important point when listing the investment alternatives with their corresponding costs and environmental impacts is to ensure a sufficient degree of comparability. Hence, the scope and level of detail as well as the quality of recorded cost and impact data need to be on an equal level throughout the listed investment alternatives.

After the costs and environmental impacts of each investment alternative are listed, the following step comprises a visualisation of resource and emission flows within a flow model of the production. This step intends to generate detailed insights regarding possible impacts on previous or following steps within the production process. Especially in case of investment objects aiming for an alternative design of the production process, this step is necessary to ensure improved production processes after implementation. In case the investment alternatives do not have a significant impact on previous or subsequent production steps, an input-output model can be used alternatively. In this case, the model represents the change of resource and emission flows through the investment alternatives.

In addition, this record and visualisation serves as a basis for the last phase of the investment process which intends to compare projected cost and environmental impact data with actual data after implementation.

The following figure compares the resource flows of electricity and heat supply for the actual and desired situation of a production site. Due to confidentiality, the amounts of heat and electricity consumptions are deleted.

Figure 33: Visualisation of current and desired situation of resource flows in form of a flow model



Source: Own illustration according to Volkswagen, 2013a

At the end of this phase, the alternatives which show insufficient feasibility are excluded from further consideration. Reasons for the identification of lacking feasibility might comprise investment alternatives exceeding the budget in terms of purchasing price or operating costs, too high risks involved with purchasing or operation of the investment alternative or the inability of implementation of an investment alternative due to technical reasons. Additional reasons for rejection might concern investment alternatives which do not provide sufficient support of strategic financial or environmental goals or investment alternatives causing the violation of given threshold values.

Finally, the following information should also be added to the shared environmental information system by the responsible planner:

- Status (e.g. 'information requested')
- Names and models of investment objects
- Supplying companies
- Purchasing prices
- Detailed operating costs
- Resource and emission flows
    - Physical quantities
    - Input-output model or flow model
- Excluded investment alternatives and corresponding reasons for exclusion.

4.4. Investment appraisal

The investment appraisal phase comprises the calculation of the relative or absolute advantageousness of each investment objective and serves as a basis for the following investment decision phase.

Regarding the financial investment appraisal, a set of indicators, derived from already established investment appraisal methods, provides a comprehensive financial assessment of each investment object. Therefore, two static and one dynamic investment appraisal methods are part of this set. While the PBP represents the time in months or years till amortisation of the investment object, the ROI sets the relation between profitability and the invested capital. In addition, the NPV recognises the time value of money and the different timings of cash inflows and outflows. Hence, detailed insights about the cash flows as well as the total added value by each investment object are contributed to the set of indicators. As a consequence the set of financial indicators conducts a basic risk assessment (PBP), assesses profitability (ROI) as well as the amount of added company value (NPV) and therefore represents a comprehensive financial assessment.

Implications for the integrated investing method

Besides a financial investment appraisal, this phase also involves an environmental investment appraisal as well as an eco-efficiency assessment. The set of indicators concerning the environmental investment appraisal contains six indicators – three financial, one environmental and two eco-efficiency indicators. The environmental indicator aims to measure the reduced environmental impact associated with each investment object and therefore is calculated based on the ESM. The remaining two indicators relate this reduced impact to the financial expenditure necessary to acquire and install the investment object or to the operating costs per accounting period.

Reduced environmental impact

As already addressed, the environmental impact is calculated based in the ESM. Appendix 1 provides a detailed introduction to the ESM and its underlying calculations. In this context, the publication of Frischknecht and Büsser Knöpfel (2013) provides extensive additional explanation and orientation regarding the correct calculation of the eco-points indicator. When calculating the eco-points indicator based on this publication, sufficient transparency as well as comparable and reproducible results can be produced. Nevertheless, the basis for this calculation is on the one hand the existence of corresponding eco-factors. This concerns the availability of eco-factors for the country under consideration as well as the environmental aspect under consideration. Furthermore, it is important to use the same set of eco-factors for the comparison of competing investment objects. On the other hand, the resource and emission flows under consideration must be determined and measured or projected.

However, the calculation of the reduced environmental impact depends on the type of investment, which is either a greenfield or a brownfield investment. With both types, the total amount of eco-points is derived by recording or projecting all relevant environmental aspects occurring within an accounting period and multiplying these with the associated eco-factors. The resulting eco-points per environmental aspect are added up to finally derive the total amount of eco-points, as exemplary illustrated in Figure 34. An exemplary calculation of an investment object can also be retrieved in appendix 3.

Figure 34: Exemplary calculation of the total environmental impact

annual environmental inventory			X	eco-factors*		=	eco-points	
Energy consumption (electricity / heat)	304,987	MWh		0.506	EP / MJ-eq.**		556	EP*10^6
CO_2 emissions	83,062	t		0.015	EP / g		1,246	EP*10^6
Fresh water consumption	558,420	m³		22.630	EP / m³		13	EP*10^6
Waste production	5,015	t		0.007	EP / g		35	EP*10^6
VOC emissions	252	t		1.475	EP / g		372	EP*10^6
						Σ	**2,222**	**EP*10^6**

* eco-factors for Germany based on Ahbe *et al.*, 2014
** assumption that total energy consumption is generated from non-renewable energy resources, 1 MWh = 3600 MJ-eq.

Source: Own illustration

Regarding brownfield investments, the reduced environmental impact is determined by the amount of avoided eco-points. Hence, the total amounts of eco-points of the current object in operation and the investment object are compared and its difference is calculated as follows:

Equation 4: Reduced environmental impact of brownfield investment objects

$$reduced\ environmental\ impact\ p.a. =$$
$$\sum eco-points\ p.a._{current\ object} - \sum eco-points\ p.a._{investment\ object}$$

Concerning the calculation of greenfield investments, no difference in eco-points can directly be calculated due to a missing reference value. Assuming that production capacities are expanded by the greenfield investment, the total environmental impact is increased. In this case, the aim is to increase the environmental impact as moderate as possible. Therefore, the amount of eco-points of a selected object, representing the current state of the art, functions as reference value. This procedure bases on the assumption that the environmental impact of the greenfield investment object is increased as moderate as possible in case it performs better than the state of the art. It also acknowledges the long-term character of investments since today's state of the art will be obsolete in future. Therefore, it is necessary to invest in the best available technology (BAT) which is assumed to perform better than the state of the art technology. Therefore, the eco-points of investment objects associated with greenfield investments are calculated as follows:

Equation 5: 'Reduced' environmental impact of greenfield investment objects

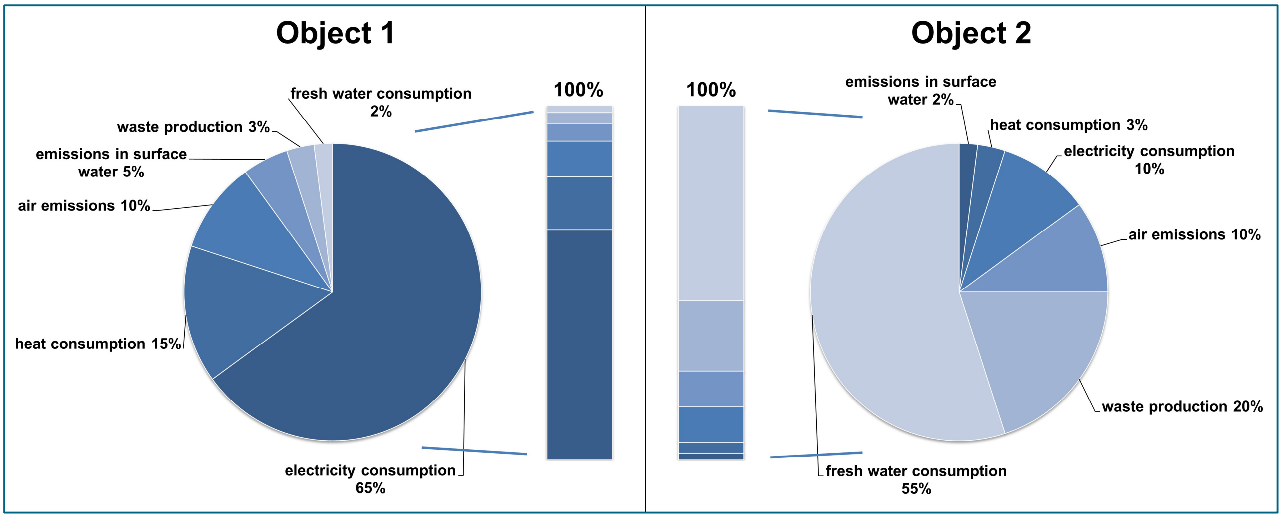
$$'reduced'\ environmental\ impact\ p.a. =$$
$$\sum eco-points\ p.a._{state-of-the-art-object} - \sum eco-points\ p.a._{investment\ object\ (BAT)}$$

The underlying assumption of both indicators measuring the reduced environmental impact holds that the subtracted amount is always smaller than the current object or the state of the art. Regarding Equation 4, it is assumed that the current object in place has grown old and thus needs to be replaced by a new investment object. Hence, the investment object is expected to perform more efficient than the current object resulting in a lower amount of eco-points. In case of capacity expansion, the investment object might provide a higher amount of total eco-points than the current object. However, to achieve a fair comparison, the projected resource and emission flows must be adapted by assuming equal production capacities for both objects under comparison. As a consequence, the total amount of eco-points of the investment object should still be lower than the total amount of eco-points of the current object.

Concerning Equation 5, it is assumed that the reference object represents the state of the art and the compared investment object characterises as best-available technology (BAT). Therefore, the BAT investment object is expected to perform more efficient than the reference object. Nevertheless, in case the BAT investment object shows a higher amount of eco-points than the state of the art, the innovative character has to be questioned. In this case, it is also questionable whether the reference object represents the state of the art. As a consequence, the position of both objects in the formula has to be changed. In case the definition of the state of the art is unknown, this logic can help to identify the investment object as BAT or state of the art. While the BAT investment object is always defined as the object with the lowest amount of eco-points, the state of the art object is defined as the object with the second lowest amount of eco-points.

While the total amount of eco-points is an important factor for determining the environmental impact of an investment object, the relative proportions of the accumulated environmental impacts might be of interest as well. For instance, a comparison of two investment objects with an equal amount of total eco-points can reveal the insight that the biggest proportion of eco-points refers to fresh water consumption for one investment object while the other object has its major impact caused by energy consumption (see Figure 35).

Figure 35: Comparison of the environmental impacts and their proportions of two fictitious investment objects



Source: Own illustration

In addition, the total amount of eco-points can be added or deducted from the total amount of eco-points of the business unit, division or investment centre in which the investment object is embedded. This step intends to project the impact of the investment object on the overall environmental performance of the functional unit or facility. By expressing this impact in a percentage, for instance, the decision-maker can assess in how far the investment object supports or hinders the achievement of the strategic environmental goal. Besides the absolute development of the total eco-points, the information regarding the relative proportions might provide additional detailed insights.

Investment eco-efficiency

Besides the increase or decrease of total eco-points by each investment object, the relation to the financial effort for acquiring and operating the investment object is vital for a comprehensive investment appraisal. However, the relation is different for brownfield and greenfield investments.

In case of brownfield investments, the indicator relates the initial cash outflow necessary to acquire the investment object (i.e. capital expenditure, in short 'capex') with the amount of reduced environmental impact of the investment object during an accounting period. The corresponding formula can be expressed as follows:

Equation 6: Investment eco-efficiency of brownfield investments

$$investment\ eco-efficiency = \frac{capex\ (in\ €)_{investment\ object}}{reduced\ environmental\ impact\ p.a.(in\ eco-points)}$$

The proposed relative indicator aims to determine the eco-efficiency which is associated with the acquisition of the investment object. Therefore, all initial cash outflows occurring prior to the regular operation of the investment object are summed up in the numerator. These cash outflows comprise the purchasing price as well as transportation and installation costs. The denominator contains the reduced environmental impact in form of the annual amount of saved eco-points. The denominator is derived by applying Equation 4.

The indicator introduced above intends to provide an assessment of eco-efficiency. The term eco-efficiency combines two types of efficiencies with economic efficiency on the one hand and ecologic efficiency on the other hand. In the context of the investment appraisal, economic efficiency of an investment object is determined by its ability to maximise production output with a minimum of financial input (Schmidt and Czymmek, 2009). On the other hand, ecologic efficiency is described as improving environmental performance by reducing the environmental impacts of a company (ibid.).

Hence, the proposed eco-efficiency indicator represents an integrated economic-ecologic assessment. As a consequence, the decision-maker is confronted with the amount of euros spent per one reduced eco-point. In conclusion, the investment object with the lowest amount of euro per reduced eco-point characterises as the investment object with the highest eco-efficiency. Nevertheless, this is a relative indicator necessitating the corresponding absolute indicators such as the total amount of reduced eco-points as well as the total amount of capital expenditure.

In case of greenfield investments, the same equation as with brownfield investments can be applied. In this case, the denominator is derived by applying Equation 5. Nonetheless, the reduction of environmental impact is imputed as it reflects the difference between a reference object which alternatively would show a worse environmental performance.

Equation 7: Investment eco-efficiency of greenfield investments

$$investment\ eco - efficiency = \frac{capex\ (in\ €)_{investment\ object}}{'reduced'\ environmental\ impact\ p.a.\,(in\ eco - points)}$$

While brownfield investment appraisals mostly involve a competing ‘business-as-usual-scenario’ in which no capital expenditure is needed, greenfield investments always require a certain outflow of capital expenditure. Hence, with regard to greenfield investments, the decision-maker might be interested in the question of how much more or less needs to be invested (i.e. spent in terms of capital expenditure) in order to reduce the amount of eco-points provided in the denominator.

However, simply adding the difference between capital expenditure of the BAT and the state of the art object to the nominator, while the denominator is derived by Equation 5, would not provide an adequate solution as the following example demonstrates. This fictitious example represents a greenfield investment with five competing investment objects with the following data:

Table 32: Fictitious example of a greenfield investment appraisal with an inadequate indicator

	Object 1 state of the art	Object 2 BAT	Object 3	Object 4	Object 5
Capex (in €)	10,000	5,000	15,000	15,000	5,000
Environmental impact (in eco-points)	100	50	150	50	150
Difference in capex to object 1 (in €) [A]	-	- 5,000	+ 5,000	+ 5,000	- 5,000
Difference in environmental impact to object 1 [B] (in eco-points)	-	- 50	+ 50	- 50	+ 50
Inadequate indicator [A/B]		100	100	- 100	- 100

Source: Own example

Regarding the relation of capex and environmental impact of the competing investment objects, Object 2 shows the best performance while Object 3 shows the worst performance in comparison to Object 1, which is defined as state of the art. Nevertheless, the indicator suggests an equal performance which might conclude a misleading interpretation by the decision-maker.

Therefore, it is necessary to take another approach to answer the decision-maker’s question regarding the assessment of both relations. The approach intends to assess the two differences in capex and environmental impact separately first, before setting them in relation within a subsequent step. When assessing capex or environmental impacts of competing investment objects, it is helpful to identify the proportional difference as this sets them into a relation to a reference value and translates the difference to a dimensionless value. The reference value is again identified as the state of the art. Finally, the second step adds the proportional difference of environmental impact to the proportional difference of capex. This step assumes that financial and environmental aspects are equally valued. If this is not the case, corresponding weighting factors have to be implemented representing the value of financial and environmental aspects for the company.

The following equation assumes equal values for environmental and financial aspects and provides the formula for the eco-efficiency relation:

Equation 8: Investment eco-efficiency relation of greenfield investments

$$eco-efficiency\ relation =$$
$$\left(\frac{capex_{comp} - capex_{ref}}{capex_{ref}}\right) + \left(\frac{env.impact_{comp} - env.impact_{ref}}{env.impact_{ref}}\right)$$

$capex_{ref}$: capital expenditure (in €) of reference investment object (state of the art)
$capex_{comp}$: capital expenditure (in €) of competing investment object
env. $impact_{ref}$: environmental impact (in eco-points) of reference investment object (state of the art)
env. $Impact_{comp}$: environmental impact (in eco-points) of competing investment object

Table 33 applies Equation 8 on the investment objects within the fictitious example above:

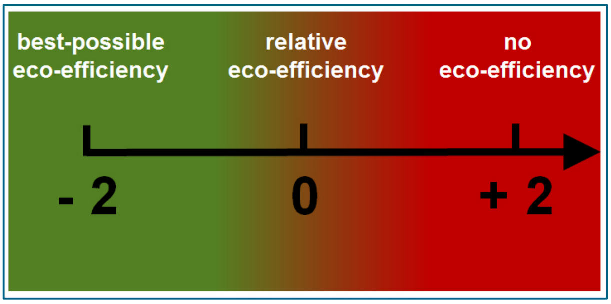
Table 33: Fictitious example of a greenfield investment appraisal with the eco-efficiency relation indicator

	Object 1 state of the art	Object 2 BAT	Object 3	Object 4	Object 5
Capex (in €)	10,000	5,000	15,000	15,000	5,000
Environmental impact (in eco-points)	100	50	150	50	150
Proportional difference in capex to object 1 [A]	-	- 0.5	+ 0.5	+ 0.5	- 0.5
Proportional difference in eco-points to object 1 [B]	-	- 0.5	+ 0.5	- 0.5	+ 0.5
Eco-efficiency relation [A] + [B]		- 1.0	+ 1.0	0.0	0.0

Source: Own example

The eco-efficiency relation of the competing investment objects ranges from - 1.0 to + 1.0 where the lowest amount represents the best investment object and the highest amount the worst investment object. In addition, the relation is able to provide additional guidance in cases of absence of many competing investment objects. This guidance originates from the theoretically best possible option that is defined as closest as possible to - 2.0. This value would represent an investment object that requires only a minimum of capital expenditure and causes a minimum of environmental impact. Investment objects with an eco-efficiency relation of zero would represent cases in which the increase in capital expenditure would be offset by the decrease in eco-points and vice versa (as for instance Objects 4 and 5 in the table above). Assuming the absence of Object 2, the decision maker would either be forced to prioritise between financial and environmental perspectives or decide for Object 1. Investment objects with positive values would represent investments with no eco-efficiency, for instance, in case capital expenditure and eco-points increase. The following figure visualises the scale of the eco-efficiency relation indicator:

Figure 36: Visualisation of the eco-efficiency relation scale



Source: Own illustration

Operating eco-efficiency

Besides the relation of initial cash outflow to the reduced environmental impact, the relation of the operating expenditure (in short ‘opex’) to the reduced environmental impact, provides additional insights and thus serves as a basis for a comprehensive investment decision. Hence, this relative indicator represents the operating eco-efficiency and is expressed by the following formula:

Equation 9: Operating eco-efficiency of a brownfield investment object

$$operating\ eco - efficiency = \frac{opex\ p.a.(in\ €)_{investment\ object}}{reduced\ environmental\ impact\ p.a.(in\ eco - points)}$$

In this formula the numerator represents the operating costs of the investment object occurring within one accounting period. These costs comprise personnel expenses, costs for raw materials, resource and energy flows, repair and maintenance. Financial costs associated with the operation of the investment object are additionally summed up in the numerator and comprise costs for depreciation, interest payments and taxes. For brownfield investments, the operating eco-efficiency contains in its denominator the result of Equation 4. Equation 5 is used for the denominator in case of assessing the operating eco-efficiency of greenfield investments as represented by the following equation:

Equation 10: Operating eco-efficiency of a greenfield investment object

$$operating\ eco - efficiency = \frac{opex\ p.a.(in\ €)_{investment\ object}}{'reduced'\ environmental\ impact\ p.a.(in\ eco - points)}$$

Again, the decision-maker might alternatively be interested in the difference between the operating expenditure of the reference object (i.e state of the art object) and the competing investment object in relation to their differences in environmental performance. Equation 11 is able to answer this question by assessing the operating eco-efficiency relation.

Equation 11: Operating eco-efficiency relation of investment objects

$$eco - efficiency\ relation =$$
$$\left(\frac{opex_{comp} - opex_{ref}}{opex_{ref}}\right) + \left(\frac{env.impact_{comp} - env.impact_{ref}}{env.impact_{ref}}\right)$$

$opex_{ref}$: operational expenditure (in €) of reference object
$opex_{comp}$: operational expenditure (in €) of competing investment object
env. $impact_{ref}$: environmental impact (in eco-points) of reference object
env. $Impact_{comp}$: environmental impact (in eco-points) of competing investment object

In contrast to the investment eco-efficiency relation, the operating eco-efficiency relation can be applied to both – greenfield as well as brownfield investment appraisals since reference values for operational expenditures are always existent with brownfield investments. Finally, the following information should also be added to the shared environmental information system by the management accounting professional:

- Status (e.g. ‘alternatives appraised’)
- Results of investment appraisal of each alternatives including
    - Reduced environmental impact
    - Investment eco-efficiency
    - Operating eco-efficiency
    - Investment eco-efficiency relation (optional)
    - Operating eco-efficiency relation (optional)
- Expected impact on strategic goals

It is important to mention in this context, that the comprising environmental impact assessment is different when appraising the same investment alternatives in different countries, due to the underlying eco-factors, which are country-specific. Hence, the shared environmental information system needs to provide the original investment appraisal data but also an option to transfer the corresponding environmental impact assessment to the environmental scarcities of the differing country under consideration.

4.5. Investment decision

Based on the previous subchapter, the proposed indicators of the integrated investing method comprise a set of financial, environmental and eco-efficiency indicators building the basis for a comprehensive investment decision.

These indicators are summarised in the table below:

Table 34: Overview of indicators of the integrated investing method

Classification	Name	Unit
Financial indicators	Capital expenditure (capex)	Euro
	Operational expenditure (opex)	Euro
	Payback Period (PBP)	Years
	Return on Investment (ROI)	Percentage
	Net Present Value (NPV)	Euro
Environmental indicators	Reduced environmental impact	Eco-points
Eco-efficiency indicators	Investment eco-efficiency	Euro/eco-point
	Operating eco-efficiency	Euro/eco-point
	Investment eco-efficiency relation (optional)	Dimensionless
	Operating eco-efficiency relation (optional)	Dimensionless

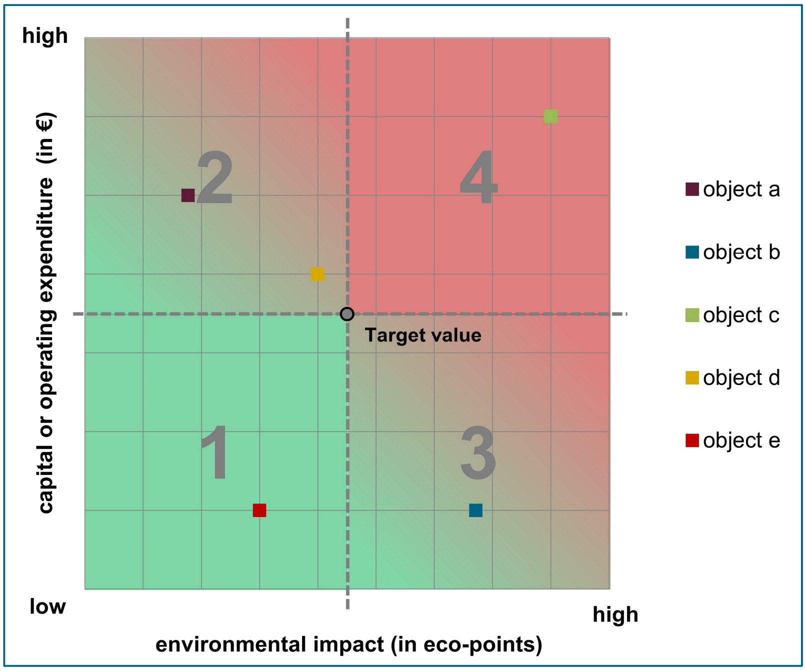
Source: Own representation

Implications for the integrated investing method

While the financial indicators are already established in common business practice, the integration of environmental indicators in investment decisions represent a novelty to a majority of management. Hence, the expression in form of a table or an integrated scorecard might not solve the problem of expected uncertainty regarding the interpretation of results. Therefore, mapping the results of the environmental indicators helps to overcome this uncertainty in interpretation (see Figure 37).

The figure below represents a generic example mapping five investment objects. The aim of this map is to visualise the amount of eco-points in relation to either the capital expenditure or the operating expenditure. In addition, several investment objects can be depicted so that decision-makers can directly benchmark the performance regarding the objects’ eco-efficiency indicators. It intends to provide additional orientation in case no alternative or only a small amount of competing investment objects is available.

Figure 37: Mapping the results of eco-efficiency indicators



Source: Own illustration

The map contains a target value as a central reference point. In case of greenfield investments, this target value can be derived by the reference object that is defined as the state of the art investment object.

In case of brownfield investments, this target value can be derived from the strategic environmental and financial goals of a company. To derive this target value, the strategic company goals need to be broken down to the specific investment decisions. With regard to the target on the y-axis, the targeted budget for the investment decision is derived from the annual company budget which is provided for capital or operating expenditure. Alternatively, the target value can be represented by the provided capex- or opex-budget of the investment case. The target value on the x-axis is derived by breaking down the targeted amount of reduced eco-points for the company, business unit or division for the year under consideration. Alternatively, the target value can be represented by the targeted reduction amount expected by the investment case. In case no target is available at all, the reference point can also be represented by the actual object in place which is intended to be substituted by the alternative investment objects.

The numbering and the colours of the map intend to provide further orientation for the decision-maker. While section one (box at the bottom left) is highlighted with green colour and represents eco-efficient investment objects with a combination of low capital or operating expenditure and low environmental impacts, section four (box at the top right) represents the opposite and thus is highlighted with red colour. The remaining two boxes represent investment objects with either high opex or capex and low environmental impact (box at the top left) or vice versa (box at the bottom right).

After mapping and interpreting the results of the indicators, the aim of this phase is to take the investment decision by identifying the investment object with the highest absolute or relative advantageousness. Regarding the advantageousness in the context of the financial indicators, the underlying decision rules change depending on the considered indicator. While the investment object with the lowest amount of capex, opex or years with the PBP is regarded as the best alternative, the highest percentage determines the best alternative in the context of the ROI. In addition, the investment object with the highest NPV assumes the highest value added and therefore is determined as the best alternative.

In the context of the environmental indicator, the lowest amount of eco-points represents the investment object with the lowest environmental impact. Regarding the eco-efficiency indicators, the amount of euros (either capital or operating expenditure) per reduced eco-point indicates the financial effort necessary to reduce one eco-point. Hence, the investment object with the lowest amount of euros per reduced eco-point indicates the most eco-efficient alternative.

In case of greenfield investments, the difference in capex or opex in the nominator can optionally be taken into consideration. In these cases, the investment or operating investment efficiency relation sets the differences in nominator and denominator in relation to each other. For these indicators, the objects with the value closest to - 2 represent the most eco-efficient alternatives. Nonetheless, these relative ratios need to be interpreted in combination with the absolute amount of reduced eco-points and the provided budget to ensure that the strategic goals are sufficiently supported.

On the one hand, these underlying decision rules help to assess each investment object with regard to their ability of supporting the strategic goals. On the other hand, however, it is unlikely that all indicators will identify the same investment object as the best solution. In this case, the decision-maker might have gained detailed insights from a comprehensive environmental and financial investment appraisal but remains uncertain regarding the upcoming investment decision.

Consequently, the integrated investing method intends a procedure that is similar to the utility value analysis since this method helps appraising investments in multi-dimensional contexts. Therefore, the results of the investment objects for each indicator need to be ranked, where the best alternative is ranked first while the worst alternative is ranked last. In the following step, the rankings of each investment object are added up so that the best alternative is determined with the lowest overall score and the worst alternative is indicated by the highest overall score.

Assuming that strategic environmental and financial goals of a company are equally valued, the financial and environmental indicators should mirror this equality. Nevertheless, the set of indicators of the integrated investing method comprises five financial indicators, one environmental indicator and four eco-efficiency indicators.

While the eco-efficiency indicators comprise an equal representation of financial and environmental aspects, the environmental indicator needs to be weighted in order to have equal importance as the five financial indicators. Yet, in case some indicators are not part of the set, the weighting need to be adjusted with the aim to arrive at an equal balance between environmental and financial aspects. However, there might be companies in which both aspects are not equally valued necessitating to adjust the weighting factors correspondingly. The following table provides the weighting factors of the proposed indicators assuming a company with strategic environmental and financial goals of equal value:

Table 35: Overview of indicators with their corresponding weighting factors

Classification	Name	Weighting factor
Financial indicators	Capital expenditure (capex)	0.2
	Operational expenditure (opex)	0.2
	Payback Period (PBP)	0.2 — 1
	Return on Investment (ROI)	0.2
	Net Present Value (NPV)	0.2
Environmental indicators	Reduced environmental impact	1
Eco-efficiency indicators	Investment eco-efficiency	0.5 (0.25)
	Operating eco-efficiency	0.5 — 1 — (0.25)
	Investment eco-efficiency relation (optional)	(0.25)
	Operating eco-efficiency relation (optional)	(0.25)

Source: Own representation

Finally, the utility value of each investment object can be summed up by the multiplication of the ranking with the corresponding weighting factor. Table 36 represents an example for ranking competing investment objects in order to determine the best alternative.

Table 36: Exemplary ranking the results of each indicator to derive the total utility value

Indicators	Object a	Object b	Object c	Object d
Capital expenditure (capex)	#1 (0.20)	#2 (0.40)	#3 (0.60)	#4 (0.80)
Operational expenditure (opex)	#2 (0.40)	#1 (0.20)	#4 (0.80)	#3 (0.60)
Payback Period (PBP)	#1 (0.20)	#2 (0.40)	#3 (0.60)	#4 (0.80)
Return on Investment (ROI)	#1 (0.20)	#2 (0.40)	#3 (0.60)	#4 (0.80)
Net Present Value (NPV)	#2 (0.40)	#1 (0.20)	#3 (0.60)	#4 (0.80)
Reduced environmental impact	#3 (3.00)	#4 (4.00)	#2 (2.00)	#1 (1.00)
Investment eco-efficiency	#3 (0.75)	#1 (0.25)	#2 (0.50)	#4 (1.00)
Operating eco-efficiency	#4 (1.00)	#2 (0.50)	#1 (0.25)	#3 (0.75)
Investment eco-efficiency relation (optional)	#1 (0.25)	#2 (0.50)	#3 (0.75)	#4 (1.00)
Operating eco-efficiency relation (optional)	#4 (1.00)	#3 (0.75)	#2 (0.50)	#1 (0.25)
Total utility value	**#2 (7.40)**	**#3 (7.60)**	**#1 (7.20)**	**#4 (7.80)**

Source: Own example

While investment Object a and investment Object b seem to perform better with regard to the financial performance, Object c and Object d perform better concerning the environmental indicator. Hence, the decision-maker faces uncertainty since no investment object comprises a satisfying environmental and financial performance at the same time. Yet, after calculating the utility value of each investment object, the comparison reveals that Object c performs better than its three competing investment objects. On the one hand, the decision-maker might choose to invest in Object c. On the other hand, the decision-maker might be interested in the relation of Object c with the maximum possible score. Assuming an ideal investment object which ranks first place in each indicator, the maximum score is three. When setting this maximum in relation to the score of Object c, the result reveals that Object a shows only 41.6 percent of what is ideally possible. Hence, the decision-maker might reject all of the investment objects deciding to restart the second phase of the investment process which intends to research additional investment alternatives.

Finally, the following information should also be added to the shared environmental information system by the responsible planner and the management accounting professional:

- Status (e.g. ‘investment decided’)
- Map with investment alternatives
- Ranking of investment alternatives
- Decision about the chosen investment object and the corresponding reasons
- Update on expected resource and emission flows (if necessary)
- Update on expected impact on strategic goals (if necessary)

4.6. Investment realisation

After the investment decision has been taken and the best available investment alternative was determined, the investment object is realised. Hence, the investment object is ordered at the supplying company resulting in a contract containing the specifications of the deal. In case of heavy machinery or other long-term assets these specifications contain agreements regarding the assembly, transportation and installation at the property of the purchasing company.

During the investment realisation phase, deviations from previously projected costs for assembly, transport or installation have to be monitored and documented. This documentation requires a coherent organisational structure with clear responsibilities and frequent communication between technical and financial staff. In case of longer realisation phases, regular project meetings are necessary to monitor the current state of implementation and to discuss cost deviations and its underlying reasons.

Implications for the integrated investing method

During installation, the environmental management accounting has to ensure that metering points are installed and implemented in the existing IT-infrastructure. In addition, the location of the installed metering equipment is essential in order to delimitate the investment object and to ensure useful monitoring of the resource and emission flows. Furthermore, the consistency of the resource and emission flows with the already existing flow model needs to be checked in order to ensure that the flow model of production depicts the corresponding flows in production reality.

Moreover, the supplying company has to sign a record of delivery in which the specifications of the investment object as well as its current state is documented in detail. Prior to the signature of the record of delivery, the investment object needs to be tested under pre-defined operating conditions to verify its technically perfect condition. With this test, it is also intended to verify whether the resource and emission flow data claimed by the supplying company fit to the actual resource and emission flows during regular operations. Besides legal aspects, the monitoring of cost and flow deviations as well as the signature of the record of delivery represent vital foundations for the subsequent phase which intends to compare projected costs and resource flows with actual costs and resource flows.

Finally, the following information should also be added to the shared environmental information system by the responsible planner and the environmental management representative:

- Status (e.g. ‘investment realised’)
- Upload of contract including specifications
- Upload of signed record of delivery
- Location of metering points
- Update of resource and emission flows (if necessary)

4.7. Investment controlling

The final phase of the investment process within companies comprises the investment controlling. Within this phase, the originally projected figures are compared to the figures which actually occur with the aim for continuously improving the investment process. This continuous improvement addresses on the one hand the quality of the investment planning phases comprising the problem situation, screening of alternatives as well as the investment appraisal phase. On the other hand the deviation analysis might reveal improvement capacities regarding the investment realisation phase. Hence, the reflection within the investment controlling phase can be structured along the previous phases of the investment process.

The considered figures for comparison contain amongst others the initial cash outflows comprising the costs for purchasing, assembling, transporting and installing the investment object. In addition, operating figures including operating costs as well as resource and emission flows in the context of the operations of the investment object are monitored and compared with originally projected figures.

In case deviations are determined, the underlying reasons have to be identified. Besides the quantitative comparison of figures, the underlying problems can also be revealed by interviewing the technical and financial professionals involved in the project. While this procedure is time-consuming, it provides the chance to reveal organisational or communication problems which are hard to identify via a comparison of costs. However, such an in-depth analysis does not need to be conducted for every case but rather for complex investment projects or for projects showing high costs deviations.

While possible reasons for deviating figures might be found within wrong projections provided by the supplying company, other reasons can be found by wrong operation of the investment object. Once, the underlying reasons for deviations are determined, actions can be formulated with the aim to reach originally intended operating conditions. Furthermore, this kind of reflection produces implications which can be considered for future similar projects.

In addition to the identification of cost deviations and its underlying reasons, this phase intends to check whether the original problem situation is solved by the investment object and whether the previously described ideal situation is reached. In case, the result of such an analysis is negative, the problem statement represents the starting point for another investment process.

The actual operating figures provide the basis for assessing the degree of strategy implementation. Hence, this phase intends to offer an answer to the question of how far the strategic environmental and financial goals are achieved. Thus, the investment controlling phase also affects future investments or investment programmes. For instance, in case, strategic financial goals are already achieved after implementing the investment object, future investment decisions might concentrate on achieving strategic environmental goals and vice versa.

Finally, the following information should also be added to the shared environmental information system by the responsible planner and the environmental management representative:

- Status (e.g. ‘investment controlling’)
- Deviations, their reasons and the lessons learned
- Measured resource and emission flows
- Impact on strategic environmental and financial goals

4.8. Summary and discussion of the method description

Summary

The method description chapter draws on the results of the method development and describes the integrated investing method along the conventional investment process within companies. Besides a short description of the activities of conventional investment steps in each phase of the investment process, the implications of the integrated investing method are added to each phase. In general, the integrated investing method expands the conventional investment process by adding an environmental and an eco-efficiency perspective based on the eco-points indicator.

Discussion

The limitations involved in the context of the method description chapter address the limitations involved with the ESM and the description along the conventional investment process. With regard to the latter limitations, the conventional investment process as described in literature contains a rather broad description of a generic process. While core processes might keep the same for a majority of companies, each company has its specific characteristics within the investment process either originating from the business environment or the company’s culture. This in turn concludes the necessity to adjust the integrated investing method as described in the context of this thesis to the specific characteristics of the investment process of each company.

Nevertheless, the core phases of investment planning, investment decision and investment realisation are expected to remain constant for all companies. There are also basic concepts on which the description of the integrated investing method draws on. These basic concepts involve on the one hand the accounting for the resource and emission flows of the investment objects as well as the expression of the environmental impact in form of eco-points. An additional core concept is represented by the expansion of the set of financial indicators by environmental and eco-efficiency indicators. These basic concepts should remain constant while the remaining steps within the method description are subject to company-specific adaptation.

Besides the adaptation of the generic description of the integrated investing method, its integration of the ESM is subject to additional limitations (see appendix 1 for a detailed introduction to the ESM). On the one hand, the scope of eco-factors is limited and might not always contain the corresponding eco-factors for all relevant environmental aspects. As a consequence, not all relevant environmental impacts of an investment object might be considered and integrated in the investment decision.

In addition, the eco-factors recognise the ecological scarcity within one country. Hence, the eco-factors are country-specific, concluding two additional limitations. While there might be a lack of country-specific eco-factors for the country of the company's operations under consideration, a cross-country comparison (i.e. investing in production site in *country a* or in production site in *country b*) is not possible. In addition, these country-specific eco-factors need to be regularly updated by independent institutions and organisations representing a third limitation in context of the ESM.

In addition, the integrated investing method suggests measuring resource and emission flows of the current equipment (for brownfield investments) or the reference equipment (for greenfield investments). In case, these measured data are not available, validity checks as well as target-actual comparisons (investment controlling) are difficult to conduct.

5. Method application

5. Method application

In the previous chapters a new method is developed that is able to integrate environmental impacts in investment decisions of companies. While the method aims to meet seven requirements which ensure scientific quality and practical applicability, the description of the method is aligned along the investment process within companies.

So far, the method is theoretically developed mostly on the basis of a critical literature review. Therefore, this chapter intends applying the developed method within daily business practice. This chapter aims to investigate two characteristics of the integrated investing method. On the one hand, the new method's practical applicability is tested. Its main aim is to test if any problems occur during implementation in practice, requiring an iterative method development and improvement process. On the other hand, the integrated investing method's ability to manage and control environmental goals is intended to be tested. Hence, the integrated investing method's ability to invest towards given strategic environmental and financial goals is investigated in this chapter.

Before applying the integrated investing method, the scientific framework is determined in the context of the first subchapter describing the case study research design. The second subchapter introduces the shared context of case studies in form of the Volkswagen Group. Besides a general introduction, the management control and investment process within the Volkswagen Group is depicted within this subchapter. The third subchapter comprises the case study reports before the reports are analysed via the cross-case synthesis method in the fourth subchapter. Finally, the fifth subchapter summarises and discusses the results of the case studies and the coss-case synthesis.

The method application is examined on the basis of case study research methodology. According to Eisenhardt (1989:534) case study research "*is a research strategy which focuses on understanding the dynamics present within single settings*". Besides its focus on contemporary dynamics, Yin (2014) states that case study research is a suitable research methodology when the researcher has no control over behavioural events. Additional strengths of case study research are the use of multiple sources of quantitative and qualitative data as well as its ability to serve explanatory and exploratory research (Saunders *et al.*, 2012). Regarding its aims, Eisenhardt (1989) summarises that case study research either intends providing description, testing theory or building theory. In addition, the author claims that case study research is a highly iterative process which enables flexibility during application (ibid.).

5.1. Case study research design

According to Saunders *et al.* (2012), research design mainly describes the practical way of how to answer the research questions. The research questions, in turn, base on the research objectives (Wallimann, 2011). Besides research questions and objectives, Philliber *et al.* (1980) add the purpose of 'blueprinting' future research by dealing with problems of research questions, identification of relevant data as well as its collection and analysis in advance of the actual research process.

Regarding case study research designs the literature discusses several layouts. These different layouts occur due to the underlying nature of the researchers' studies. The following table summarises and compares three popular case study research designs:

Table 37: Overview and comparison of different case study research designs

Eisenhardt (1989)	Stake (1995)	Yin (2014)
Getting started by defining research questions and identifying a priory construct.	**Set criteria for selection of cases** by differentiating between intrinsic cases or instrumental cases.	**Define research questions** of the case study by most likely asking 'how' or 'why' questions.
Selecting cases with the help of theoretical sampling.	**Define research questions, issues and information questions** to specify possible cause-and-effect relationships or potential problems.	**State theoretical propositions** underlying the research.
Crafting instruments and protocols by referring to multiple data collection methods using qualitative and quantitative data.	**Data gathering** including the organisation of access and permissions as well as the definition of data gathering types.	**Define the unit(s) of analysis** by delimitating 'the case' and considering the research questions of the case study.
Entering the field by overlapping data collection with data analysis.	**Analysis** by aggregation, categorisation and interpretation of data.	**Linking data to propositions** to choose an appropriate data analysis method.
Analysing data with the help of within-case analysis or cross-case analysis.	**Case study researcher roles** by reflecting on the approach of researcher and the study.	**Set criteria for interpreting case study's findings** by either identifying statistical significance or benchmarking findings against rival theories or explanations.
Shaping hypotheses with iterative tabulation of evidence or replication logic for cross-case analyses.	**Triangulation and validation** of data and findings.	
Enfolding literature by comparing findings with external similar or conflicting literature.	**Report writing** including structuring the report, identifying target readers and story-telling.	
Reaching closure when theoretical saturation occurs.		

Source: Own representation, according to Eisenhardt, 1989; Stake, 1995 and Yin, 2014

While the three case study research designs above show differences in the amount of research steps as well as its descriptions, similarities regarding basic elements of general research designs (i.e. research objectives and questions as well as data collection and analysis) can be observed. In the context of this thesis a synthesis of the basic elements of the three given case study research designs results in the concluding description of the case study research design.

They can briefly be summarised in form of the following bullet points:

- Research objectives and questions
- Propositions underlying the research design
- Defining the unit of analysis
- Selection criteria and case selection
- Data collection
- Data analysis
- Case study reporting

Pilot Case Study

Yin (2014) suggests examining a pilot case study in order to test or refine the planned case study research design. This pilot case study, however, should not be part of the final set of case studies under consideration since it represents an imperfect case. Nevertheless, it is important to analyse the lessons learned and to conclude the corresponding implications for the research design.

The pilot case for this case study represents a comparison of energy supply concepts for electricity and technical heat for a testing site. The selection criteria of the pilot case base on two reasons. First, the scope and quality of data provided a sufficient basis for testing the integrated investing method. Second, the management and the employees of the service engineering department showed great interest in the development and use of the integrated investing method. Hence, they were open-minded but also critical partner that provided extensive feedback on the integrated investing method. The pilot case study report with the corresponding implications for the case study research design is situated in appendix 2.

5.1.1. Case study research objectives and questions

The research objective of this thesis is to develop a method to systematically integrate environmental impacts in investment decisions within companies (integrated method) and to verify its practical applicability. While the first part of this objective – the actual method development – is already met with the previous chapters, the remaining part (i.e. the verification of the integrated method's applicability) represents the objective of the case study research. In addition, the integrated method's objective, which is the ability to achieve strategic environmental and financial goals of an existing company, is in the focus of the case study research of this thesis. Hence, in the introductory chapter the fourth sub-research question is formulated as follows:

Sub-research question 4:
Does the method testing verify the practical applicability of the developed method and the management and control of strategic environmental goals of an existing company?

This sub-research question includes two parts which are separated for the purpose of case study application in order to align to the two remaining research objectives.

Case study research question 1:
How can the newly developed method successfully applied in business practice?

This research question intends to apply the integrated method in practice on the one hand and to identify possible problems and limitations during implementation on the other hand. Depending on the type, origin and severity of possible problems, the case study research design allows conducting an iteration cycle which enables further method development and subsequent testing.

Case study research question 2:
How to manage and control the achievement of strategic environmental and financial goals of a company?

This research question aims to the purpose of current investment decisions in companies, which intend to support achieving its strategic financial goals. Therefore, the previous research question ensures a systematic integration of environmental impacts in investment decisions. This research question in turn tests the ability to manage and control strategic environmental goals so that these goals can be achieved besides achieving financial goals.

While the first case study research question focuses on the application of the integrated investing method in investment processes of single investments, the second case study research question focuses on the influence of an investment program (i.e. a set of single investments) on achieving strategic goals. Therefore, these two case study research questions are addressed by separate case studies which either intend to answer one of the two questions.

5.1.2. Propositions underlying the research design

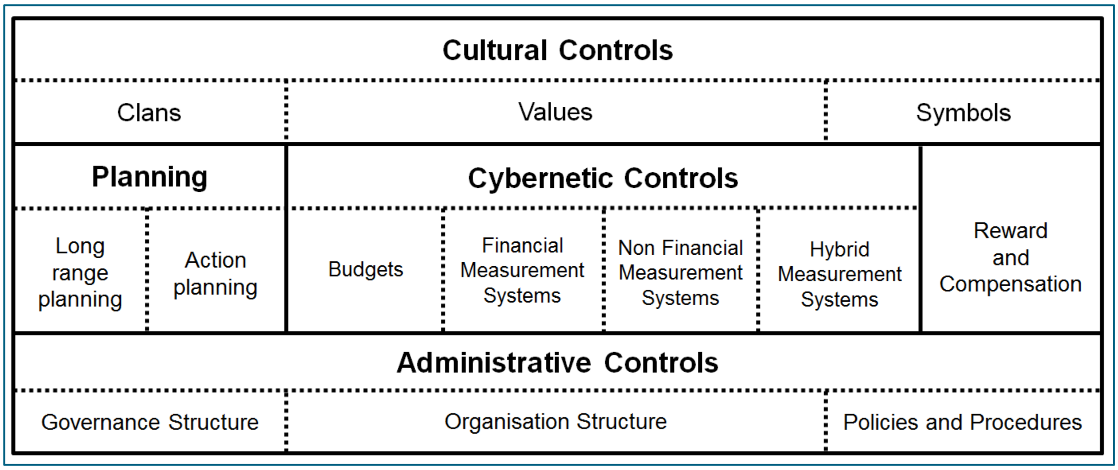
This subchapter briefly outlines the propositions underlying the case study research design. According to Yin (2014), it is necessary that the researcher is aware of the fundamental propositions and concepts since it influences the direction of case study research. Eisenhardt (1989:536) states in this context that "*if these constructs prove important as the study progresses, then researchers have a firmer empirical grounding for the emergent theory*."

The principal-agent problem as originally introduced by Jensen and Meckling (1967) holds that principals, which are mostly the owners of a business, hire agents (i.e. executive managers) to run the business. As the agents maximise their utility, this does not necessary maximise the utility of the principal. The term 'agency costs' describes the decreasing value of a company while the agent maximises the own utility (Zimmerman, 2010). In addition, the problem is intensified by a situation of asymmetric information, in which the agent has access to more crucial information than the principal. As a consequence, principals set objectives which the agents have to aim at, in order to avoid or decrease agency costs and to ensure that the interests of the agent comply with the interests of the principal.

These overarching goals can roughly be separated along the two major schools of thought arguing over the purpose of a business. On the one hand, there is the shareholder value concept as described by Rappaport (1999) arguing that the only purpose of a business is to maximise its shareholder value. As a consequence, the management's single goal is to focus on financial targets which results in a maximisation of the company's profits. On the other hand, the stakeholder value concept as discussed by Freeman (1984) acknowledges the influence and interests of various stakeholders of a company. As a consequence, company goals have to reflect a consensus of the interests of all important stakeholders to guarantee long-term success of a business. Hence, the goals, which the management has to aim at, also include non-financial values which might comprise environmental goals amongst others.

Independent from the amount and content on given strategic goals, agents organise their internal information and decision-making system with the help of management control systems. Strauß and Zecher (2013) analyse various scopes and definitions of management control systems (MCS) which are described in textbooks and academic journals. The authors conclude a core understanding of MCS which "*regards MCS primarily as information-providing devices used for decision-making purposes in context of organizational goals*" (ibid:264). Furthermore, the majority of analysed approaches show a process of three core functions which range from planning, over performance measurement (cybernetic controls) to reward and compensation (see middle level in the following figure).

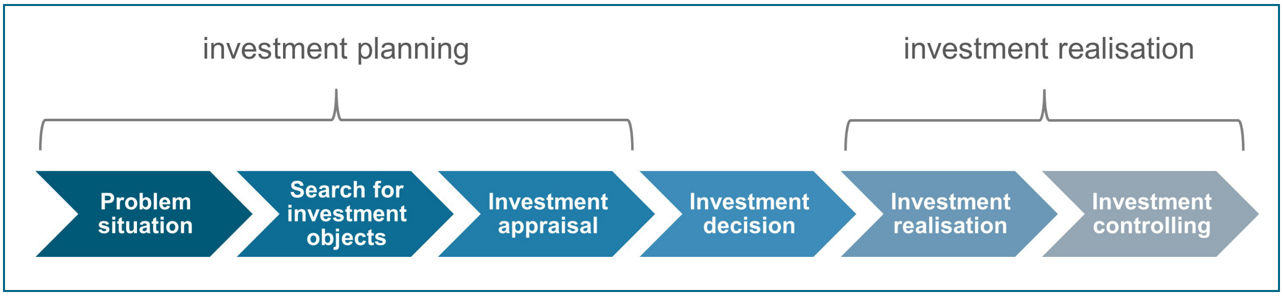
Figure 38: Process and core functions of management control systems



Source: According to Strauß and Zecher, 2013:261

When focusing on the cybernetic controls function, performance measurement includes the structure and utility of indicators providing information which function as a basis for decision-making in companies (Gladen, 2011). With regard to investment decisions, the underlying proposition holds that each investment decision is based on previous investment planning. The result of the investment planning process is expressed in a set of indicators resulting from investment appraisals. In front of these investment appraisals, the phases of problem definition and search for alternatives are located as illustrated in the following figure. (Poggensee, 2011)

Figure 39: Phases of an investment process



Source: Own illustration, according to Prätsch et al., 2012 and Poggensee, 2011

Besides the underlying propositions regarding strategic goals which managers need to aim at as well as the concept of MCS including the corresponding performance measurement indicators within the investment process, the case study intends to study potential problems during implementation of the new developed method. Hence, additional propositions regarding implementation problems of indicators or methods also need to be part of this subchapter. In this context, Grundy (1998:43) claims, that implementation is "*frequently the graveyard of strategy*". This statement even gets intensified by Liesen *et al.* (2013) who complain the lack of implementation especially for sustainability and environmental strategies.

Günther (2008) elaborates on the necessity to explore the underlying reasons for lacking implementation with the help of hurdle analysis. According to the author, hurdles or disruptive factors slow down, impede or block decision-making processes. On the basis of the principal-agent problem, the analysis is structured along the steps of the decision-making process (which is in line of the investment process as well) and the participating actors of the corresponding steps.

Based on this structure, hurdles and their underlying origins can be identified and classified in the following categorisations:

- Lack of objectives
- Lack of controls
- Lack of information
- Lack of knowledge
- Lack of reward and compensation

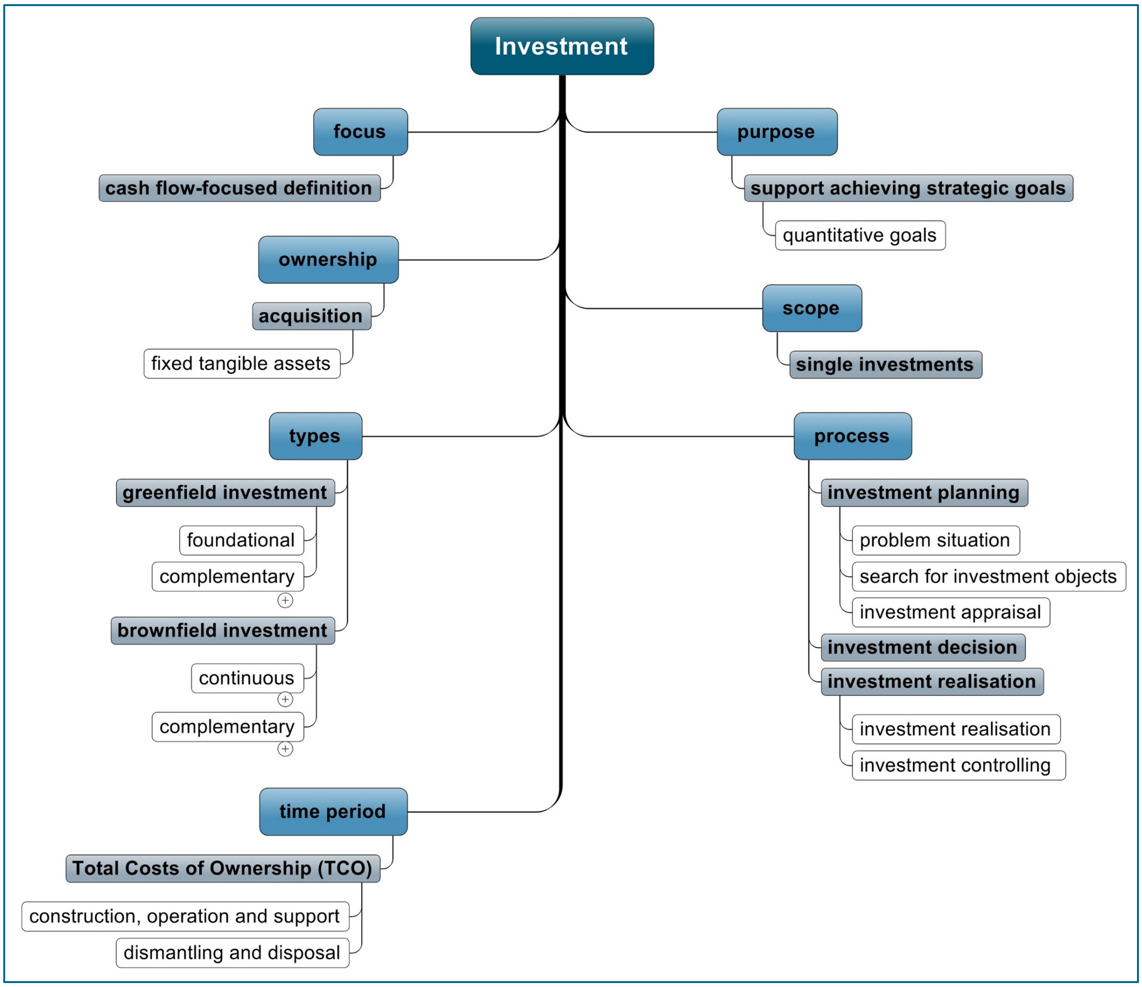
Finally, the identified and classified hurdles are evaluated and visualised before measures intending to reduce or remove hurdles can be formulated. (ibid.)

5.1.3. Defining the unit of analysis

This subchapter deals with the definition and framing of the actual case to be studied. Regarding the case studies focusing on the first case study research question, the definition of the case can be transferred from the definition of investments which is provided in the second chapter of this thesis.

Hence, the case studies analyse single investments that are defined as cash outflows, enabling to acquire fixed tangible assets for greenfield or brownfield sites, which generate (imputed) cash inflows over the time of the operator's ownership, aiming to eventually help a company in achieving its strategic goals. The following figure summarises the defined attributes and characteristics of investments to be studied within the case study research of this thesis:

Figure 40: Definition of investment used in the context of this thesis



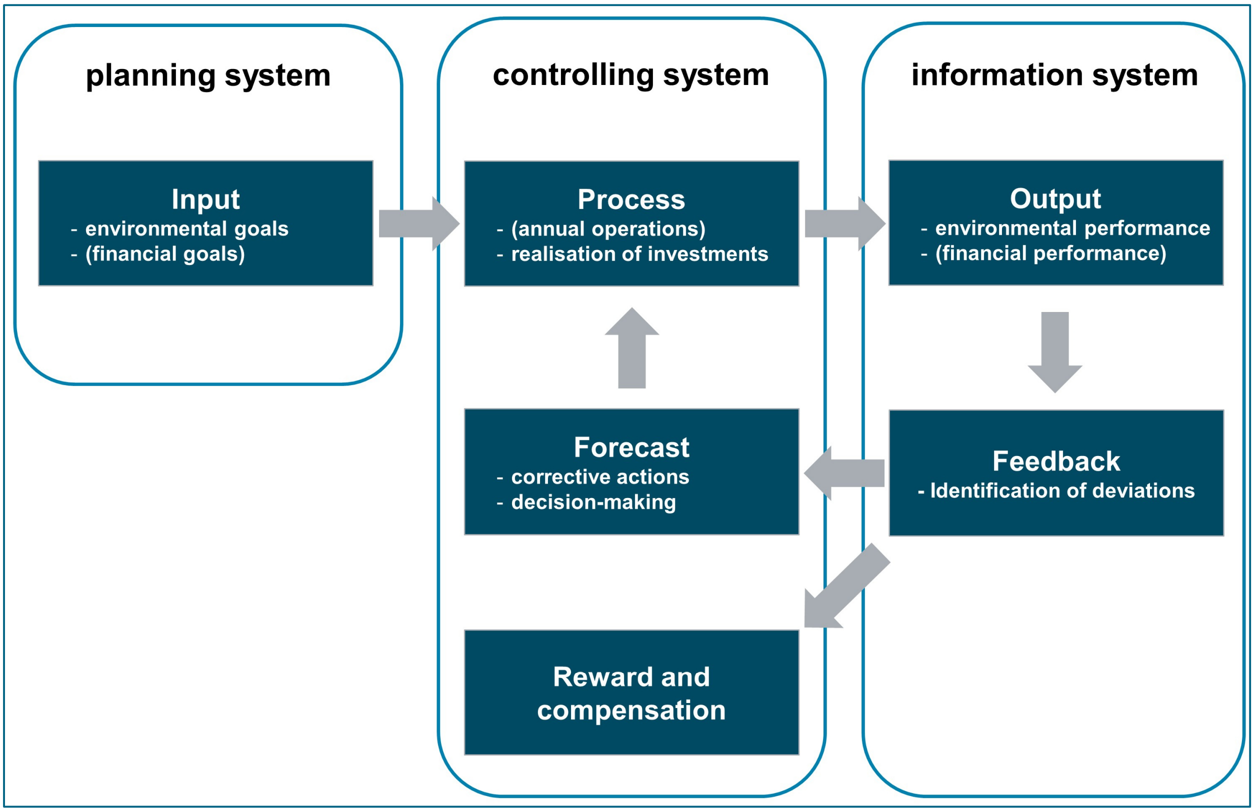
Source: Own illustration

Regarding the starting phase of the case, the investment process as described in literature and within the previous chapter sets the boundary. Thus, the case starts with the investment planning phase and ends after the investment realisation.

With regard to the second case study research questions, the unit of analysis focuses on an investment program and its implications on managing and controlling strategic environmental goals. Hence, the unit of analysis is defined according to management control systems. According to Schäffer (2013), the core of management control systems comprise a cooperation of a planning system, a control system and an information system. While the planning system is concerned about setting goals as input of a process, the output of this process is pictured in form of a report and feedback within the information system. Finally, the control system consists out of corrective actions, which influences can be forecasted as inputs to the process. (Zhang, 2014)

The following figure defines the environmental management control system in the context of the case studies addressing the second case study research question:

Figure 41: Environmental management control system in the context of this case study research

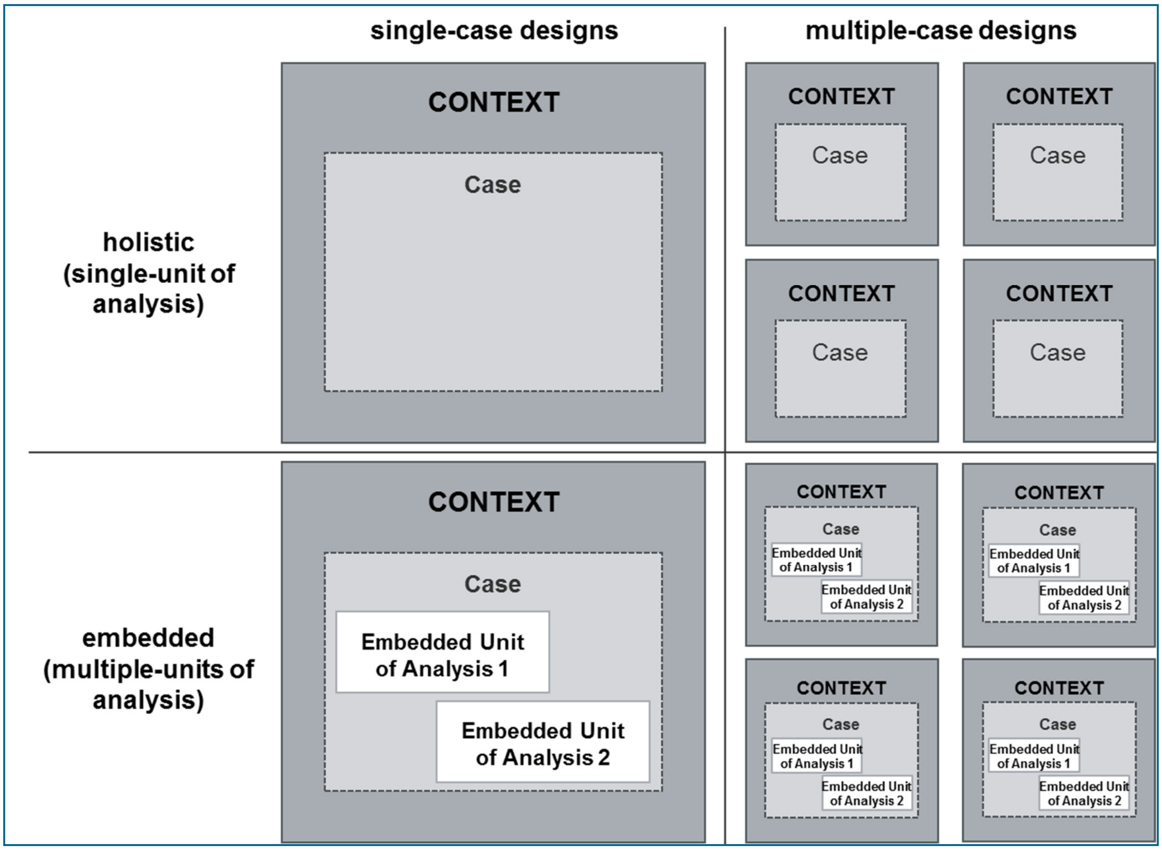


Source: According to Schäffer, 2013; Zhang, 2014; Strauß and Zecher, 2013

The environmental management control system in the context of the case studies of this thesis assume that the financial management accounting system already ensures the achievement of strategic financial goals. Hence, the focus is set on the management and control of strategic environmental goals. In addition, it is assumed that there is a corporate compensation system rewarding the management for achieving the given environmental goals. While usual operations might also contribute to achieving the environmental goals, the focus of the case studies is set on the realised investments within one accounting period.

Yin (2014) differentiates between four major types of case study designs (see Figure 42). While single-case studies can involve either one unit of analysis (holistic single-case design) or several units of analysis (embedded single-case design), multiple-case studies comprise one unit of analysis within several contexts (holistic multiple-case design) or several units of analysis within several contexts (embedded multiple-case design).

Figure 42: Basic types of case studies



Source: Yin, 2014:50

In the context of the method testing of this thesis, the first type of case studies intends to apply the integrated investing method in practice on the one hand and to identify possible problems and limitations during implementation on the other hand. Therefore, the holistic multiple-case design is most suitable since the same unit of analysis (i.e. application of the integrated investing method in an investment process) is studied in several contexts. Yin (2014) states that the underlying rationale of holistic multiple-case design is a replication logic. Problems can be identified and tested if they either occur frequently or if they depend on the applied context.

With regard to the second type of case studies, the intention is to apply the environmental management control system as illustrated in Figure 41 in several contexts. Therefore, the holistic multiple-case design is most suitable as well.

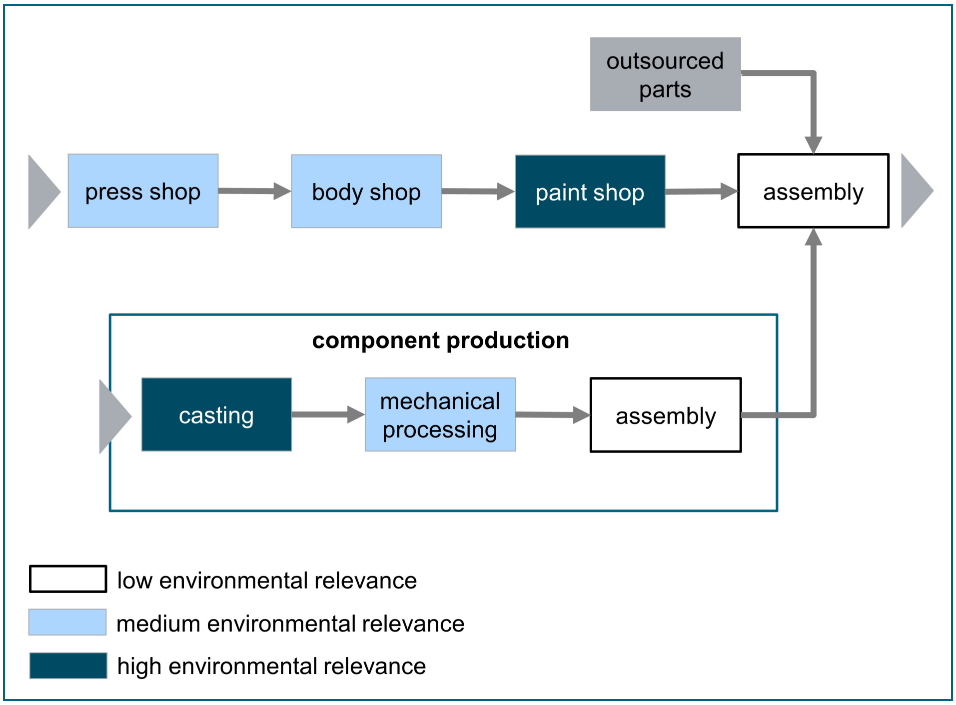
5.1.4. Selection criteria and case selection

This subchapter intends to outline the methodology and rationale behind selecting the cases in which the integrated investing method is applied. Regarding the methodology, Eisenhardt (1989) claims that statistical sampling from a ‘population’ of cases is inappropriate for case study research design. In order to select reasonable cases, the researcher should make use of theoretical sampling. One method of theoretical sampling, suggested by the author, is to select cases in order to fill theoretical categories (ibid.). This methodology is practiced in the context of this chapter. In addition, the two-phase approach, which is suggested by Yin (2014), is considered due to the high amount of available cases. However, this procedure was extended by an additional step since three selection criteria were necessary to compose the final set of cases.

Step 1 – Selection according to the context of the case

The 18 cases, in which the integrated investing method is applied, share the same general context which is the automobile production within the Volkswagen Group. However, the context of automobile production is too broad since each production area within the production process shows its own characteristics with significant influence on the corresponding cases. Therefore, the context of each case orients along the various areas of the automobile production process (see Figure 43).

Figure 43: Simplified overview of the automotive production process



Source: Own illustration according to Kropik, 2009 and Volkswagen, 2015b

According to Kropik (2009), the automobile production process can be separated between a core process (consisting out of press shop, body shop paint shop and assembly) which is mainly owned by the automotive original equipment manufacturer (OEM) and non-core processes which are mostly sourced out to a supplying company. In this context, Stratmann (2010) claims, that the production depth within the Volkswagen Group is higher than its competitors. Hence, there is also a large in-house production of semi-finished goods (called 'component production') which is also taken into consideration. Regarding the theoretic sampling methodology, the selection of cases represents the theoretical categories of the automobile production process within the Volkswagen Group.

Thus, the production areas under consideration are listed as follows:

- Component production
- Press shop
- Body shop
- Paint shop
- Final assembly

In a first step, the 18 cases can be allocated to the identified production areas. The following list represents the names of the cases with their corresponding areas within the automobile production process:

Table 38: Overview of the 18 cases and their corresponding production areas

No.	Context/production area	Case name
1	Technical development	Installation of new ventilators
2	Technical development	Utilisation of waste heat
3	Technical development	Comparison of water pumps
4	Technical development	Installation of new windows
5	Technical development	Renovation of ventilation centre
6	Technical development	Management and control of environmental goals
7	Body shop	New construction of a body shop
8	Component production	New cylinder head production line
9	Paint shop	New paint shop on a greenfield site
10	Paint shop	Comparison of exhaust air treatment concepts
11	Paint shop	Comparison of application process concepts
12	Paint shop	Comparison of waste water treatment concepts
13	Energy supply	Installation of a combined heat and power unit
14	Press shop	Retrofit of a transfer press
15	Press shop	Comparison of transfer press models
16	Press shop	Comparison of transfer press types
17	Production site	Management and control of environmental goals
18	Five production sites	Management and control of environmental goals

Source: Own representation

Based on the table above, it is obvious that the cases for the production areas body shop and component production are selected for further research due to the absence of rival cases. It is additionally obvious, that there is no case available for the final assembly production area.

However, the environmental declaration of Volkswagen (2015b) claims that the final assembly is characterised by moderate environmental relevance. As a consequence, the fact that there is no case available in the context of final assembly does not limit the quality of case study research for this thesis, since environmentally relevant investments are not expected in this production area.

Furthermore, Table 38 contains cases which cannot be allocated to one of the five production areas above. These cases contain the cases in the context of technical development, energy supply and production sites. Nevertheless, three of these cases deal with the management and control of environmental goals and thus qualify for further research regarding the second case study research question.

Step 2 – Selection according to the investment type

Finally, there are rivalling cases for the production areas paint shop and press shop. For these remaining cases, the second step of the selection process is represented by the introduction of an additional selection criterion.

Since the integrated investing method differentiates between greenfield and brownfield investments within its investment appraisal step, it is helpful to choose the type of investment as selection criterion. Hence, the intention is to compose a balanced set of cases between both types of investments. The cases which are already selected within the previous steps and their corresponding investment type classification is represented within the following table:

Table 39: Overview of the selected cases and corresponding investment types

No.	Context/production area	Case name	Investment type
1	Technical development	Management and control of environmental goals	Both types
2	Body shop	New construction of a body shop	Brownfield
3	Component production	New cylinder head production line	Greenfield
4	Production site	Management and control of environmental goals	Both types
5	Five production sites	Management and control of environmental goals	Both types

Source: Own representation

Since cases one, four and five represent cases addressing the management and control of environmental goals on the basis of a set of single investments, they include both types of investments. In contrast to that, the second and the third case show one brownfield and one greenfield investment type. In conclusion, the selection of the two cases regarding the production areas press shop and paint shop need to comprise one brownfield investment case and one greenfield investment case.

The following table represents the remaining rivalling cases with their corresponding investment types:

Table 40: Overview of remaining cases and corresponding investment types

No.	Context/production area	Case name	Investment type
1	Paint shop	New paint shop on a greenfield site	Greenfield
2	Paint shop	Comparison of exhaust air treatment concepts	Greenfield
3	Paint shop	Comparison of application process concepts	Greenfield
4	Paint shop	Comparison of waste water treatment concepts	Greenfield
5	Press shop	Retrofit of a transfer press	Brownfield
6	Press shop	Comparison of transfer press models	Greenfield
7	Press shop	Comparison of transfer press types	Greenfield

Source: Own representation

When analysing the table above, it is obvious that there is only one brownfield investment type (i.e. case number five) amongst the listed cases. As a consequence, the paint shop case needs to represent a greenfield investment type.

Step 3 – Selection according to the scope of the case

However, the four remaining cases can all be classified as greenfield investments. Therefore, this criterion does not represent a sufficiently differentiating selection criterion. Therefore, the third selection criterion is the scope of the case. While the first case in the list represents the assessment of a complete paint shop, the remaining three cases compare concepts of single processes. Therefore, the first paint shop case was included for further case study research since it represents a more comprehensive case than the competing cases.

Consequently, the final set of cases selected for case study research in the context of this thesis is listed in the following table:

Table 41: Final set of cases and their corresponding production areas and investment types

No.	Context/production area	Case name
1	Component production	New cylinder head production line
2	Press shop	Retrofit of a transfer press
3	Body shop	New construction of a body shop
4	Paint shop	New paint shop on a greenfield site
5	Technical development	Management and control of environmental goals
6	Production site	Management and control of environmental goals
7	Five production sites	Management and control of environmental goals

Source: Own representation

5.1.5. Data collection and data analysis

Data collection

Data collection builds the basis for case study research since it represents the collected evidence. In this context, Eisenhardt (1989) claims that the combined collection of quantitative and qualitative data is a major strength of case study research. Yin (2014:121) adds that the collection of data from multiple sources of evidence is vital to achieve data triangulation which "*helps to strengthen the construct validity*" of the case study.

With regard to the case studies of this thesis, the data collection intends to establish data triangulation by collecting evidence from multiple sources, which are represented by the different persons involved in the investment process. While tabular documents from the management accounting department provide original projections of cash flows, additional tabular documents from the technical planning department provide resource and emission flows regarding several investment objects. These documents can serve as a basis to collect quantitative evidence about the underlying data for investment appraisal calculations. In addition, documentary data such as e-mails, administrative records, reports and other digital documents provide augmented evidence. Furthermore, data gaps, resulting in a fuzzy chain of evidence, were filled with interview questions, which were sent per e-mail to the involved employees.

Due to confidentiality regulations of the Volkswagen Group, data regarding resource and emission flows were adjusted according to a secret factor which is only known to the author. Therefore, the resource and emission flows are not disclosed directly, but their proportions keep the same so that data analysis is still possible.

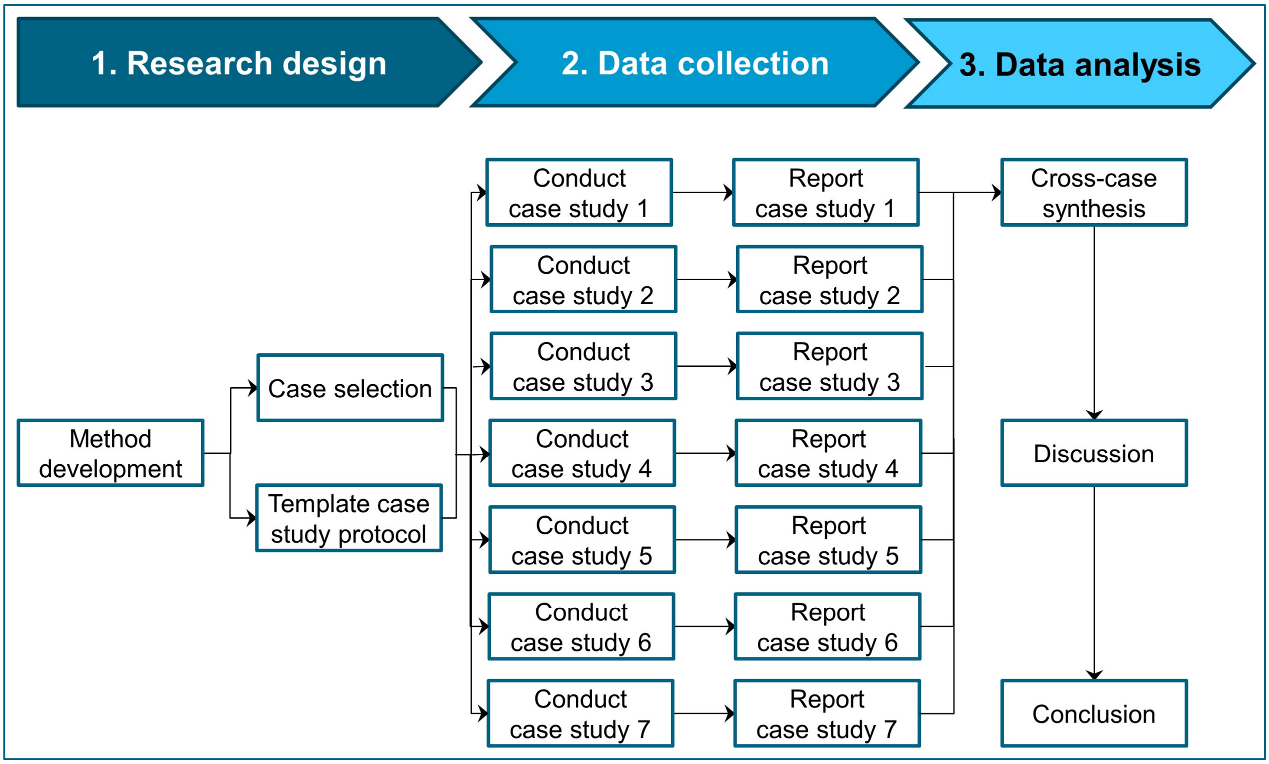
Data analysis

According to Yin (2014:133) data analysis "*is one of the least developed aspects of doing case studies*". With this introductory statement, the author points towards the low amount of analytic techniques and towards the tendency of researchers to neglect setting up a data analysis strategy beforehand. This prior determination of an analysis strategy is important to provide guidance not only through the analysis step but also concerning the data collection step. In case the data analysis strategy is determined beforehand, the researcher can ensure collecting the kind of evidence which is able to analyse later on.

Yin (2014) describes four general strategies of data analysis, which help the researcher to establish a logical chain from research questions, over underlying propositions and data collection to data analysis. Two of the strategies are combined in the context of this thesis. On the one hand, data analysis relies on underlying propositions and on the other hand on the development of case descriptions. This decision is closely connected to the holistic multiple-case research design and the analytic techniques as provided by Yin (2014). The author discusses five analytic techniques which aim to ensure internal validity and external validity. In the context of multiple case studies, Yin (2014) recommends cross-case synthesis as most preferable. According to the author "*the findings [are] likely to be more robust than having only a single case*" (ibid.:164).

Figure 44 shows the research design and procedure of multiple-case study research. In the context of this thesis, the first phase of the procedure consists of the development of the integrated investing method. In addition, the design phase comprises the selection of cases in which the integrated investing method is applied. Parallel to that, the case study protocol template is designed to ensure a standardised data collection procedure. The subsequent phase is the data collection phase which implies the collection of evidence and writing of the individual case study reports. The concluding data analysis phase comprises the cross-case synthesis and the implications for the practical applicability of the integrated investing method.

Figure 44: Multiple-case study procedure



Source: Own illustration, based on Yin, 2014:60

5.1.6. Template of the case study protocol

The template of the case study protocol mainly intends to increase reliability in data collection so that the protocols of the cases can be compared to each other via cross-case synthesis within the subsequent data analysis phase. It also serves as a guidance document for the researcher during the data collection phase. In accordance with Yin (2014), the template is structured in three sections. While the first section provides an overview of the case study, the second section comprises the collected evidence. Finally, the third section includes the layout of the case study report which is subject to cross-case comparison later on. This layout differentiates between case studies assessing single investments (section 3.1.) and case studies concerning investment programs (section 3.2.).

Section 1: Overview of the case study

1. Description of the context
    - Operating context and characteristics
    - Special issues for consideration
2. Description of the case
    - Description of the unit of analysis
    - Delimitation of the case

Section 2: Collected evidence

Types of data and data sources

- Tabular documents:
    - Financial data
    - Resource and emission flow data
- Documentary data:
    - E-mails
    - Administrative documents
    - Additional digital documents
- Interview data
    - Context data:
        - Date of interview
        - Name of interviewee
        - Job profile of interviewee
- Interview questions:
    - E-mails with additional questions aiming to fill data gaps in order to establish a coherent chain of evidence

Section 3.1.: Layout of the case study report for single investments

1. Name of the case study
2. Context of the case
3. Description of the case along the investment process
    1. Problem situation
        1. What is the reason for investment need?
        2. Description of the current situation (incl. flow model)
            a. Current amount of eco-points
        3. Description of the desired situation (incl. flow model)
            a. Targeted amount of eco-points
    2. Search for investment objects
        4. Projection of capital expenditure
        5. Projection of operating expenditure
        6. Projection of resource and emission flows
        7. Projection of eco-points
        8. Visualisation within a flow model
        9. Optional: exclusion of alternatives and possible reasons
    3. Investment appraisal
        10. Calculation of payback period
        11. Calculation of return on invest
        12. Calculation of net present value

13. Calculation of reduced environmental impact
14. Calculation of investment eco-efficiency
15. Calculation of operating eco-efficiency
16. Calculation of investment eco-efficiency relation (optional)
17. Calculation of operating eco-efficiency relation (optional)

4. Investment decision
   18. Determination of a target value
   19. Mapping of investment alternatives
   20. Summary of figures and rankings
   21. Calculation of utility values
5. Investment realisation
   22. Are metering points installed and implemented in IT-infrastructure?
   23. Is coherence with flow model given?
   24. Is the record of delivery signed?
6. Investment controlling (optional)
   25. Any deviations in financial data or environmental data?
   26. What are the reasons for the identified deviations?
   27. What are the lessons learned for future investments?
   28. Was the original problem solved by the investment?
   29. Was the ideal situation reached by the investment?
   30. How far have strategic goals been achieved by the investment?

Section 3.2.: Layout of the case study report for investment programs

1. Name of the case study
2. Context of the case
3. Description of the case along the management control process
   1. Input in form of environmental goals
      31. What are the environmental goals of the case?
      32. How can they be transferred to the eco-point indicator?
   2. Realisation of investments
      33. Which investments have been realised in the time period under consideration?
   3. Environmental performance measurement
      34. What was the effect of the investments on the environmental performance of the unit of analysis?
      35. What is the performance in the context of the achievement of environmental goals?
      36. Is there any deviation of actual environmental performance from targeted environmental performance?
   4. Feedback and corrective actions
      37. What corrective actions need to be executed to ensure achieving the targeted environmental goals?

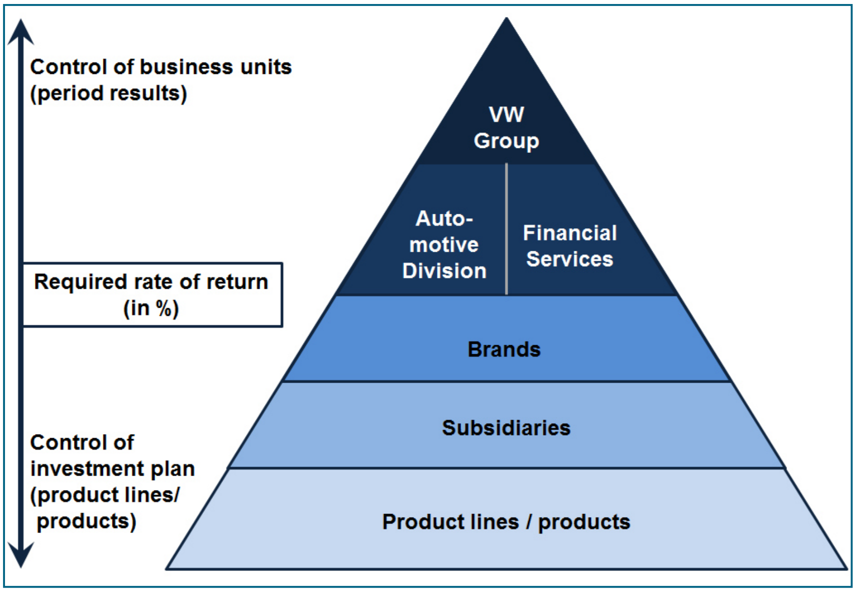
5.2. Introduction to the Volkswagen Group and its investment process

The Volkswagen Group, headquartered in Wolfsburg, Germany, can be divided into two main divisions with the Automotive Division on the one hand and the Financial Services Division. The Financial Services Division comprises banking services, insurances, financing, leasing and other mobility services. The Automotive Division mainly consists of the manufacturing sites of the 12 brands Volkswagen Passenger Cars, Volkswagen Commercial Vehicles, Audi, Škoda, Seat, Bentley, Bugatti, Lamborghini, Porsche, MAN, Scania and Ducati. (Volkswagen, 2015a)

Today, over 592,600 employees in 118 production sites manufacture 335 vehicle models worldwide. In 2014, the 10,213,000 manufactured vehicles resulted in a sales revenue of more than 202.5 billion € and a profit after tax of about 11.068 billion €. According to the annual report for the year 2014, the total investments in property, plants and equipment amounted to 12.012 billion € and thus rose by 10.2 percent in comparison to the previous year. The Group's return on the invested capital based on the profit after tax (ROI) was at 14.9 percent in the year 2014. In this context, the Group's ROI is higher than the internally set required rate of return which is determined at 9 percent. (ibid.)

When describing the investment process within the Volkswagen Group, it is necessary to roughly explain the management control system beforehand. As illustrated in Figure 45, the management control system is operationalised in form of a pyramid where the Group management accounting is on top, brand and subsidiary management accounting in the middle and product line or product management accounting at the bottom. The overarching measure is the targeted rate of return which is reported within the periodic results of the business units as well as the investment plan of the product lines or products.

Figure 45: Application of required rate of return within the Volkswagen Group



Source: Based on Volkswagen, 2010:12

On the basis of this pyramid, there are several committees responsible for investment decisions. Generally, the following rule can be applied: the higher invested amount, the higher the committee which is entitled to take the investment decisions.

The highest committee situated at the top of the pyramid comprises members of the Volkswagen Group Board. It is responsible for determining the investment framework of the brands which functions as an orientation for several years. The basis for this determination is comprised of the product strategy with its sales forecast, the occupancy of the sites, the finance plan as well as the targeted rate of return. (Adelt *et al.*,2008)

The second level within the pyramid is represented by the investment committees of the brands which are composed by the board of directors of each brand. This committee is responsible for the decision regarding the examination of an investment program. The basis of this decision is comprised of the consistency of the investment program with the investment framework and the monitoring of legal issues and financial capabilities. (ibid.)

The third level of the pyramid is represented by the brand investment committee which comprises the members of the brand's management board. This committee is responsible for large-scale projects such as investments necessary to develop, produce and market new products. In addition, investment decisions with the intention to expand production capacities or large-scale rationalisation investments are decided within this committee. The basis for decision-making is the sum of investment appraisals necessary to examine each large-scale project as well as sales and costs forecasts in case the investment decision is about the introduction of new products. (ibid.)

Finally, the fourth and lowest level of the pyramid is represented by the executive management. After the decision to introduce a new product is taken one level higher, the executive management is responsible to execute the project, or a part of it, in the most efficient way. Hence, the investment decisions are broken down to investment appraisals on single machines and its alternatives. (ibid.) Table 42 represents an overview of the hierarchy of investment decisions with its different investment committees and corresponding responsibilities:

Table 42: Hierarchy of investment decisions at the Volkswagen Group

Type of authorisation	Subject of decision	Basis for decision-making	Committee(s)
1. Investment framework	Investment plan for several years	Product strategy, site occupancy, finance plan, rate of return	Board of the Volkswagen Group
2. Examination of investment program	Investment program	Consistency with investment framework, legal issues, finance capability	Boards of directors of each brand
3. Examination of large-scale projects	New products, production capacity expansion of rationalisation	Sum of investment appraisals of single investments, sales forecast, costs forecasts	Management boards of each brand
4. Examination of single investments	Single investment objects	Investment appraisal, benchmark with alternatives	Executive management

Source: Based on Adelt et al., 2008:123

The method testing of this thesis focuses on the lowest level of the hierarchy of investment decisions. Therefore, the decision for investment programs, new products or production capacity expansions or rationalisation measures have already been taken beforehand on higher levels of the hierarchy. As a consequence, the investment program plan also includes the total capital investment need which determines the budgets for the single investments.

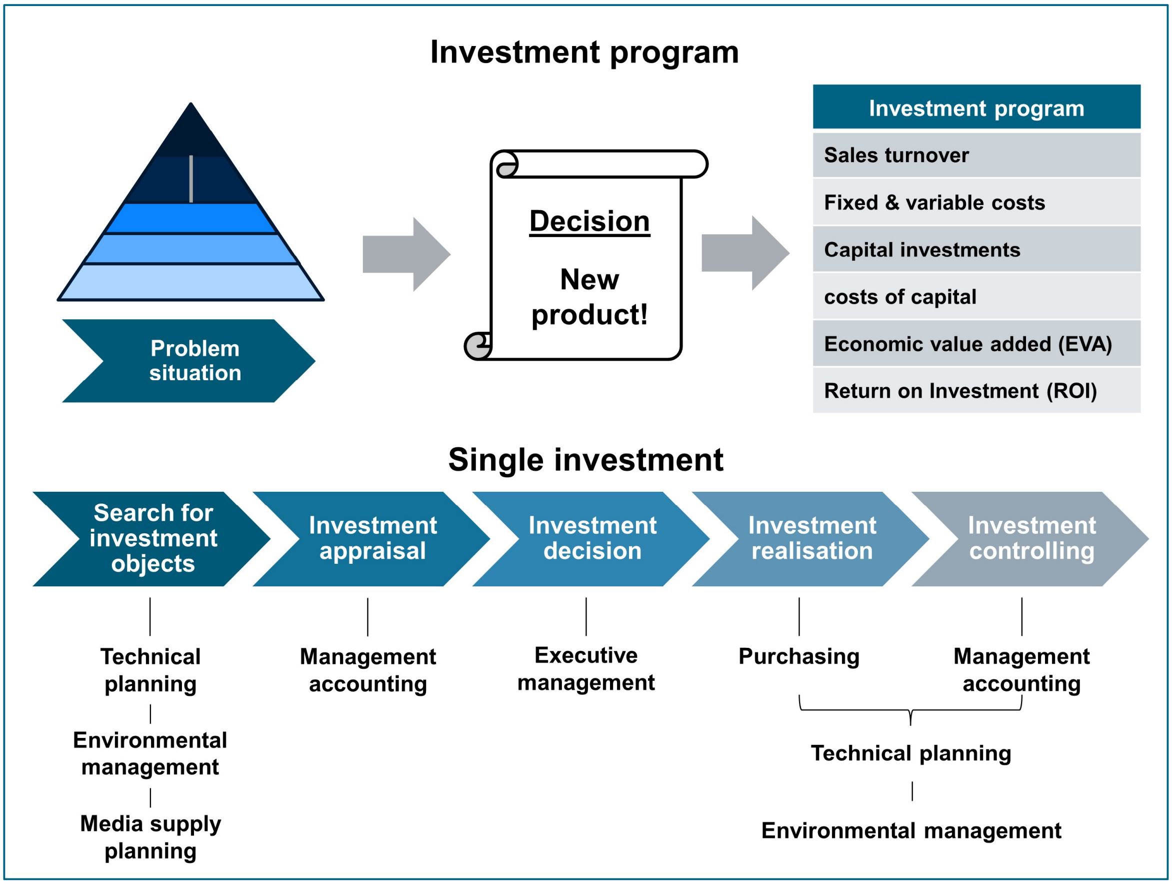
Adelt *et al.* (2008) also describe the single investment process. The authors claim that the operational investment process starts with the search for technically feasible alternatives. The technical planning department conducts this search for alternatives and hands the results over to the management accounting department, together with a recommendation of the technically best feasible investment object. Within this phase, the resource and emission flows of the alternatives are projected based on the specifications by the supplying companies. After a first validity check, these projected resource and emission flows are also handed to the environmental management representative, which is asked to provide a statement whether or not the expected resource and emission flows would violate any given legal threshold values. In case of a violation, the corresponding investment object is excluded from further consideration. Afterwards, the expected resource and emission flows are reported to the media supply planning department of the plant to assess the feasibility of installation. As with the environmental management representative, the media supply planning department is also asked for statement regarding the feasibility of successful installation.

After these operational steps, the management accounting department takes the remaining investment alternatives and conducts an investment appraisal by calculating the net present value, the rate of return as well as the payback period of each investment object. The recommendation for the technically and financially best investment objects is handed over to the executive management which can either reject or take the investment decision. In case of rejection, the investment process starts again. In the opposite case, the purchasing department is instructed to start negotiations with the supplier of the investment object.

Finally, the investment realisation phase comprises purchasing, installation and operation of the investment object. The technical planning department also monitors the installation process and hands over the installed investment object to the operating personnel. It also assists the management accounting department with technical data from the investment planning and realisation phases. In some cases, metering points are installed and implemented in the environmental information system. In these cases, the technical planning department also cooperates with environmental management department to ensure data validity of resource and emission flows. (ibid.)

The following figure provides an overview of the investment process within the Volkswagen Group along an example of a new product investment program. It also connects the process at Volkswagen to the single investment process as process described in academic literature and the structure of the integrated investing method.

Figure 46: Overview of the investment process at the Volkswagen Group



Source: Own illustration based on Adelt et al., 2008

Besides the description of the investment process at the Volkswagen Group as a sub-process of management accounting, the environmental management accounting process also needs to be described. So far, the environmental management accounting process at the Volkswagen Group concentrates on the standardised collection, aggregation, monitoring and reporting of environmental aspects. These environmental aspects are represented in form of a set of environmental indicators which is described in detail within a group standard. This standard intends to provide a standardised and compulsory basis for the definition of terminology, scope of measurement, the reporting interval, responsibilities and requirements regarding environmental indicators. (Volkswagen, 2013b)

The environmental aspects are recorded on plant level according to a group standard and reported via the group environmental information system. However, the environmental management department of each plant is responsible for organising the environmental accounting process. As a consequence, a variety of environmental information systems is in operation within the different plants of the Volkswagen Group. While some plants conduct environmental accounting via Excel spreadsheets, other plants operate a software-based environmental information system with various users metering points supplying environmental data. Independent from the system in place, the environmental management representative of the plant is responsible for the validity of the environmental aspect data, which is reported to the headquarters via the group environmental information system (ibid.). Nevertheless, the group environmental management, which is situated in the headquarters, also conduct validity checks and sends additional requests regarding data explanation to the plants. In addition, the external auditing company verifies the environmental aspect data throughout the environmental management audit process (Volkswagen, 2015b). Furthermore, in context of the publishing process of the Group sustainability report, another external auditing company conducts validity checks of environmental data on a random basis (Volkswagen, 2014a).

5.3. Case study reports

5.3.1. New cylinder head production line

This case study intends to provide answers to the research question of how to successfully apply the integrated investing method into business practice. Therefore, the integrated investing method is applied based in a real-life investment case to identify possible problems and limitations during implementation.

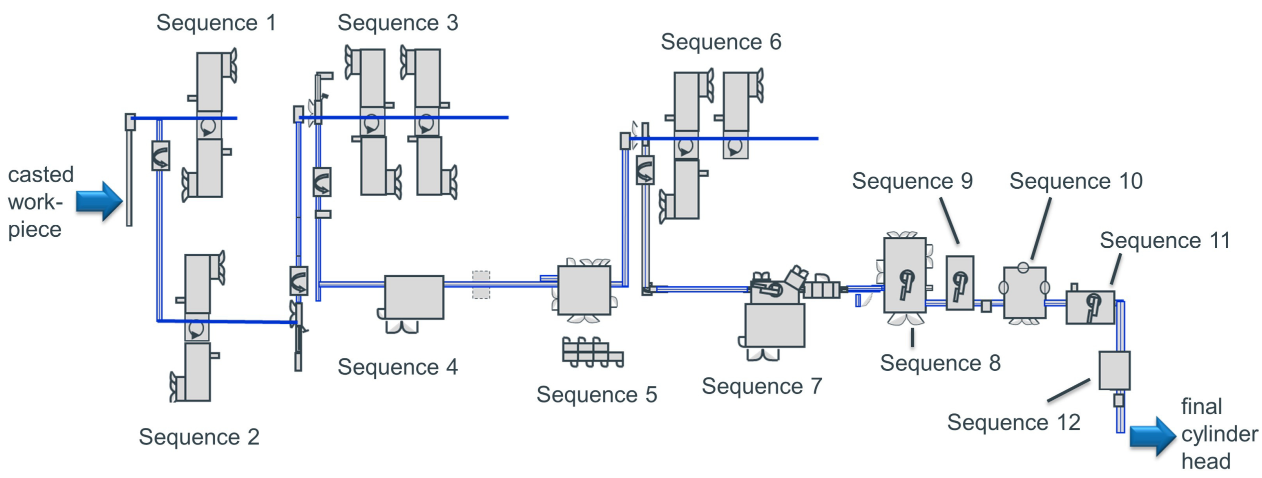
Context of the case

The context in which the integrated investing method is applied within this case study is a greenfield investment in a new cylinder head production line of a new production site. The cylinder head production, as part of the components production, roughly consists out of three steps which is casting, mechanical processing and assembly (Kropik, 2009).

With regard to this case study, the cylinder head production focuses on the mechanical processing and assembly steps and thus excludes the previous casting process. Hoag (2006:80) describes the cylinder head production process as "*a series of machines linked together in transfer lines*" starting "*with a series of rough operations, followed by an initial wash and then the finish operations*.". During these operations, several machining processes such as drilling, milling, broaching, tapping and cutting are examined to manufacture the final cylinder head (ibid.).

The process under consideration is roughly depicted in the following figure:

Figure 47: Overview of operating sequences of a cylinder head mechanical processing production line



Sequence 1 – drilling locating holes for subsequent alignment
Sequence 2 – rough mechanical processing
Sequence 3 – rough mechanical processing
Sequence 4 – pre-washing
Sequence 5 – assembly (VSR/VF)
Sequence 6 – fine mechanical processing
Sequence 7 – final washing
Sequence 8 – assembly cover elements
Sequence 9 – leakage testing
Sequence 10 – assembly valves
Sequence 11 – assembly valve trains
Sequence 12 – measuring and quality control

Source: According to Volkswagen, 2015c

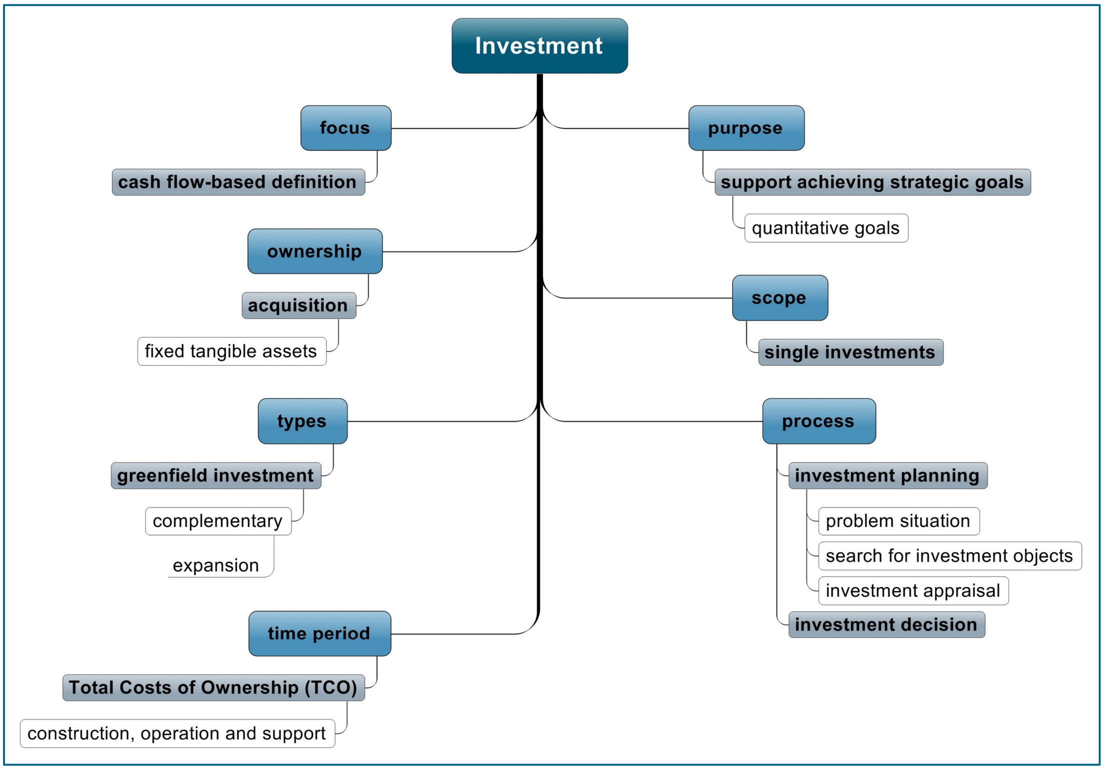
Description of the case along the investment process

The case study deals with a greenfield investment for a new production site aiming to support the strategic goal of meeting the increased local demand within a world region. Hence, production capacities need to be expanded requiring the construction of new production sites. The process involves a company-owned planning department which plans and constructs the site. Once the site is turnkey-ready, it is handed over to the plant operator. The acquisition of this new fixed tangible asset is realised via inner-company transfer prices.

Since the new site is currently under construction, the investment process cannot comprise all phases due to a lack of data and thus misses the realisation phase. Regarding the time period under consideration, the construction, operation of the newly built production site is in the focus of this case study.

The following figure provides an overview of the attributes and characteristics within this case study:

Figure 48: Overview of attributes and characteristics of the investment within this case study



Source: Own illustration

Problem situation

The starting point of this case study is the formulation of an investment need originating from the plan of building a new engine production site. The necessity, in turn, for building the engine production site originates from fast-growing regional demand which requires and expansion of production capacities.

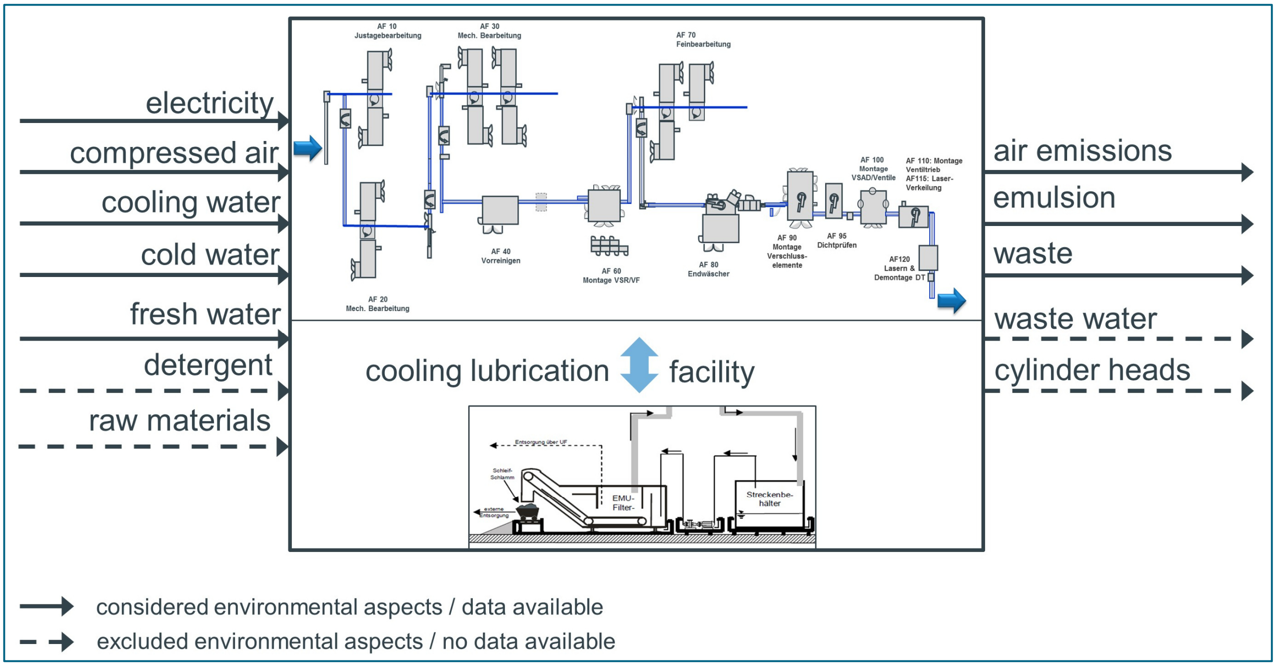
On the one hand, the description of the integrated investing method advises depicting the current situation with a visualisation in form of a flow model and the calculation of the total amount of eco-points, caused by current operations. On the other hand however, the lack of such a current operation in place makes such a representation obsolete. Nevertheless, the description of the desired situation contains the objective to keep the added environmental impact as moderate as possible. With this objective, the desired cylinder head production line should at least be built according to the current state of the art.

Search for investment objects

As described in the context of this case study, the investment object represents a cylinder head production line which consists of a series of machines examining several machining processes. Regarding the research for alternative investment objects, the machining processes keep the same since the form of a cylinder head does not allow any alternative machining processes. The state of the art of machining processes requires cooling lubricants. The function of cooling lubricants is to diminish deterioration of machines by cooling and lubricating. In addition, the metal chips are transported away from the work piece enabling high process reliability and quality (Hoag, 2006).

However, the use of cooling lubricants necessitates high amounts of fresh water consumption and causes increased effort regarding waste water treatment. The waste water, consisting out of an emulsion between fresh water and cooling lubricants also carries metal chips. Hence, the metal chips need to be separated from the emulsion via centrifugation before the emulsion is processed in a subsequent waste water treatment facility. Hence, the state of the art of mechanical processing uses cooling lubricants and thus the resource and emission flows are depicted in the following flow model:

Figure 49: Flow model of conventional mechanical processing with cooling lubricants

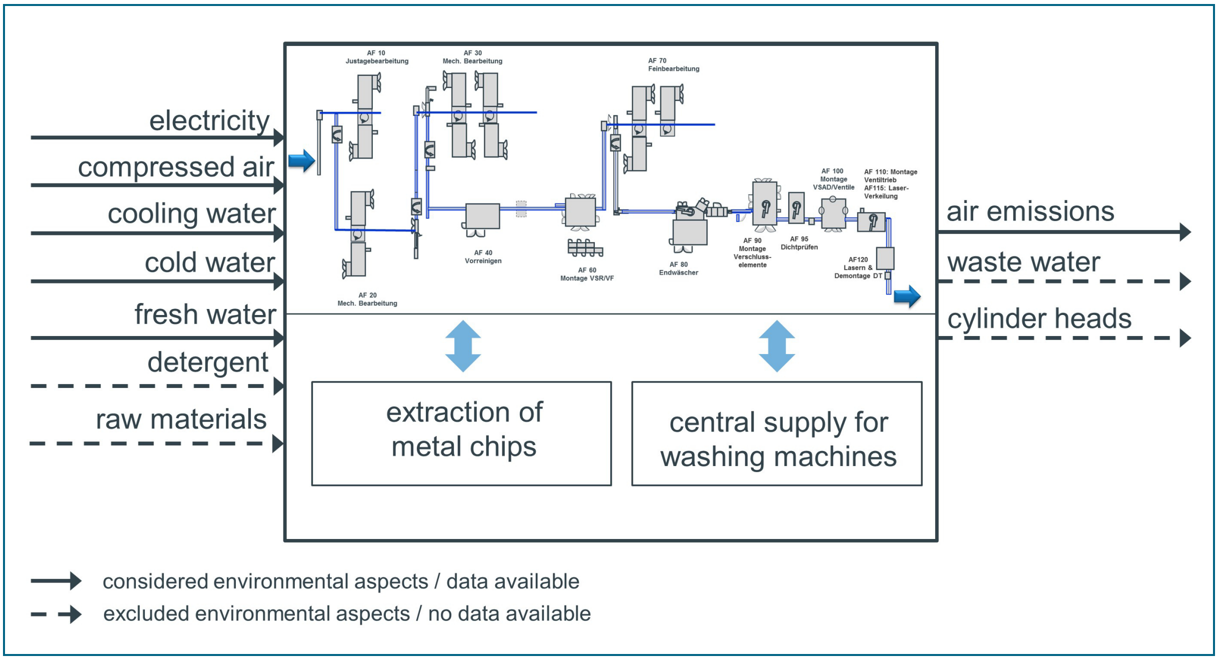


Source: According to Volkswagen, 2015c

Since the mechanical processing steps keep the same in order to produce a cylinder head, alternative investment objects focus on the use of cooling lubricants. An innovative approach represents the use of minimum lubrication. The aim of this approach is to minimise the use of lubrication while still preventing deterioration. The lubricant shows a bigger surface and therefore comprises a higher cooling capacity. In addition, the lubricant evaporates during its use in mechanical processing. While this minimises fresh water consumption and waste water treatment, it requires the use of compressed air to transport the metal chips away from the work piece. In addition, the danger of low-speed detonations increases due to the absence of processing water and the accumulation of gaseous emissions. Hence, facilities extracting air emissions are needed to avoid the risk of low-speed detonations.

The following illustration depicts the resource and emission flows of mechanical processing using minimum lubrication technique.

Figure 50: Flow model of mechanical processing with minimum lubrication



Source: According to Volkswagen, 2015c

Due to confidentiality restrictions, it is not possible to represent real figures for the resource and emission flows of both alternatives. Therefore, the following table provides the comparison of resource and emission flows between minimum lubrication and cooling lubrication, which were adjusted by a secret factor that is only known to the author of the dissertation.

Table 43: Resource and emission flows of minimum lubrication in comparison to cooling lubrication

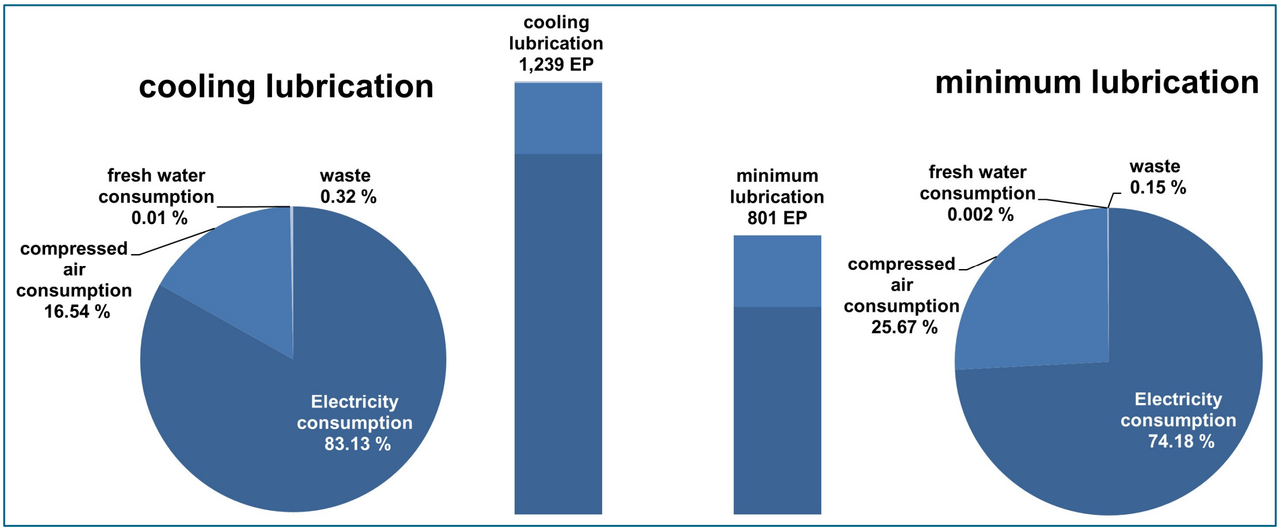
Resource or emission flows	Cooling lubrication	Minimum lubrication	Difference
Electricity consumption (in kWh/a)	16,613,307	16,664,473	+ 00.31 %
Electricity for cold water provision (in kWh/a)	27,704,477	7,290,652	- 73.68 %
Electricity for cooling water provision (in kWh/a)	1,405,950	1,491,175	+ 06.06 %
Electricity for air extraction (in kWh/a)	1,842,803	1,980,700	+ 07.48 %
Compressed air consumption (in Nm^3/a)	84,518,185	84,734,100	+ 00.26 %
Fresh water consumption (in m^3/a)	6,722	748	- 88.87 %
Waste in form of emulsion (in m^3)	536	-	- 100.00 %
Waste in form of detergent (in m^3)	14	19	+ 32.85 %

Source: Own calculations based on Meyer, 2015 [data adjusted according to secret factor]

Besides moderate increases in electricity consumption for cooling water provision, air extraction and provision of compressed air, the significant differences can be observed for cold water provision, fresh water consumption, emulsion production and detergent consumption. The biggest difference is the fresh water consumption originating from the avoidance of emulsion and its treatment facility. That is why there is also no waste in form of emulsion listed for the minimum lubrication technology. Nevertheless, additional detergent is needed since an increased effort is necessary to clean the work pieces during the washing sequences. In addition, a significant amount of cold water can be reduced due to the better cooling performance of the minimum lubrication technique.

With regard to the environmental impacts of both investment objects, the cooling lubrication technology shows higher impact on the environment with 1,239 eco-points than the minimum lubrication technology with 801 eco-points. However, when assessing the proportions of the eco-points in detail, the high differences in fresh water consumption and waste production do not account for the difference in total eco-points between both objects. In fact, the main reason for the difference in eco-points can be found in the reduced electricity consumption of the minimum lubrication technology in comparison to the cooling lubrication technology. The following figure summarises and compares the environmental impact between both investment objects:

Figure 51: Comparison of environmental impacts of cooling lubrication and minimum lubrication technology



Source: Own illustration

Investment appraisal

Due to confidentiality of sensitive data, the original figures provided by the two suppliers were adjusted according to the secret value which is only known to the author of this dissertation. However, the proportions keep the same which still enables to draw conclusions from the provided case study data.

Regarding the calculation of the important indicators analysing the investment, there is no access to the original data regarding the operating expenditure of the joint production site which is currently in place. Hence, there is no calculation of imputed cost savings possible that can serve as income or gains. As a consequence, the indicators, payback period, return on investment and net present value could not be calculated. Hence, the following table summarises the result of the investment appraisal phase within the integrated investing method:

Table 44: Investment appraisal of two mechanical processing technologies

Indicator	Cooling lubrication	Minimum lubrication
Total capital expenditure (in €)	144,361,800	148,894,900
Annual operating expenditure (in €)	6,326,346	3,393,436
Payback period (in years)	-	-
Return on investment (in percent)	-	-
Net present value (in €)	-	-
Total environmental impact (in eco-points)	1,239	801
Reduced environmental impact (in eco-points)	-	438
Investment eco-efficiency (in €/saved eco-point)	-	339,942.69
Operating eco-efficiency (in €/saved eco-point)	-	7,747.57
Investment eco-efficiency relation	-	- 0.32
Operating eco-efficiency relation	-	- 0.82

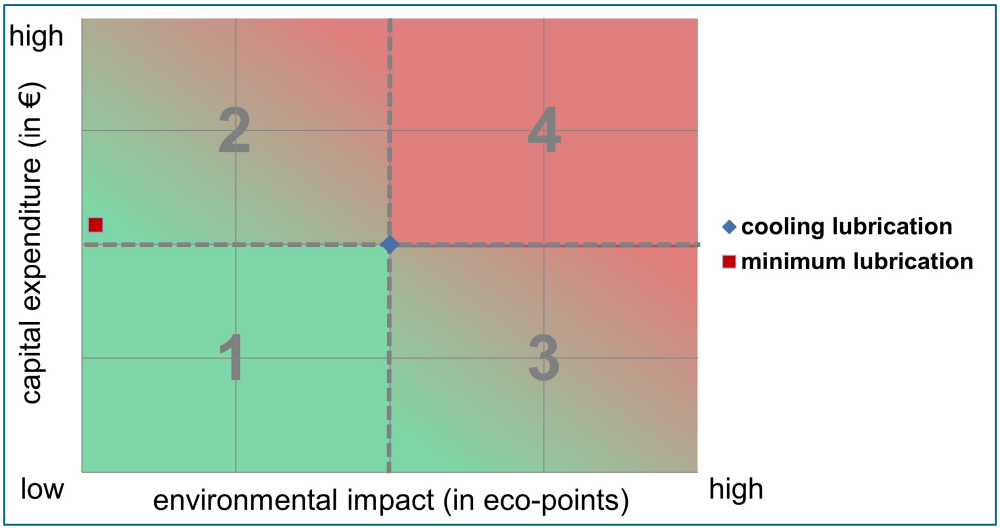
Source: Own calculations based on Meyer, 2015 [data adjusted according to secret factor]

Investment decision

The integrated investing method introduces the idea of mapping the alternatives on a 2x2-matrix where the y-axis maps the financial perspective and the x-axis represents the environmental perspectives. The middle of the matrix is based on the targeted budget and the amount of targeted reduced environmental impact in form of eco-points. However, within this case study, no targeted amount of reduced environmental impact and the targeted capital investment budget could be determined.

Nevertheless, a map can still be created with slight adjustments. Instead of the financial or environmental budgets functioning as a reference point, the amounts of capital expenditure and eco-points of the investment object representing the current state of the art can be situated as reference point. Hence, the map comparing the cooling lubrication technology with the minimum lubrication technology can be illustrated as follows:

Figure 52: Mapping the capital expenditure and environmental impact of both technologies of this case study



Source: Own illustration

In addition, the integrated investing method suggests ranking the indicators of the competing investment alternatives in order to identify the investment object with the highest relative advantageousness. Nonetheless, due to the limited amount of investment objects and the lack of financial indicators such as ROI, PBP and NPV, the weightings need to be adjusted first in order to ensure a balanced weighting between financial and environmental perspectives. Since there are no comparable values for the eco-efficiency indicators, the set of weighting factors only comprise financial and environmental indicators. Thus, the weighting factors in the context of this case study are as follows:

Table 45: Weightings in the context of this case study

Classification	Name	Weighting factor
Financial indicators	Capital expenditure (capex)	0.5
	Operational expenditure (opex)	0.5
Environmental indicators	Environmental impact	1

Source: Own representation

Finally, the ranking of the cooling lubrication technology and the minimum lubrication technology can be executed. The following table summarises the rankings and the total utility values of the competing investment objects within this case study:

Table 46: Total utility value of cooling lubrication technology and minimum lubrication technology

Name	Cooling lubrication	Minimum lubrication
Capital expenditure (capex)	#1 (0.5)	#2 (1.0)
Operational expenditure (opex)	#2 (1.0)	#1 (0.5)
Environmental impact	#2 (2.0)	#1 (1.0)
Total utility value	**#2 (3.5)**	**#1 (2.5)**

Source: Own calculation

As a conclusion of the comparison of the total utility value provided in the table above, the management decided to invest in the minimum lubrication technology.

5.3.2. Retrofit of a transfer press

This case study intends to provide answers to the research question of how to successfully apply the integrated investing method into business practice. Therefore, the integrated investing method is applied based in a real-life investment case to identify possible problems and limitations during implementation.

Context of the case

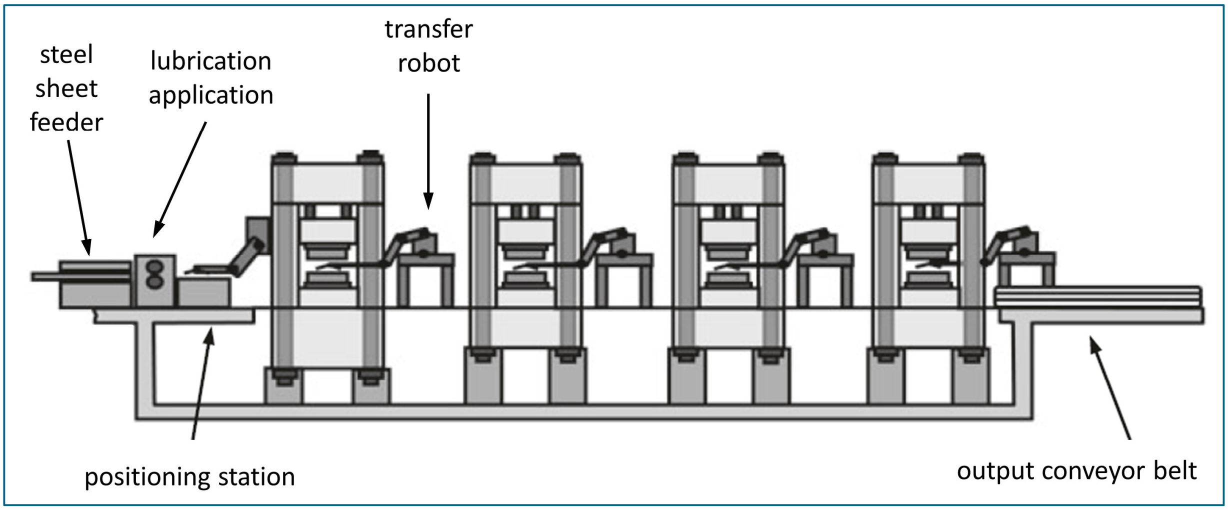
The press shop represents the context of this case study and is mostly the start of production at the automobile manufacturer. The steel sheet is transported from the supplier in form of coils to the press shop of the automobile manufacturer. After cutting the steel sheet in pieces, these pieces are put into the press in order to form parts such as roofs, side elements, doors or flaps which are welded together in the subsequent body shop. (Kropik, 2009)

There are different press types which form different car body parts depending on the size and complexity of the car body part and the capabilities and free capacities of the press itself. Press lines consisting out of different press types are used in order to form complex car body parts. (Birkert *et al.*, 2013) The car body parts are produced in batches, transported to an interim storage and delivered to the body shop via Just-In-Time (JIT) principle. Besides ensuring a sufficient degree of quality, the throughput rate is an important parameter to measure the efficiency of a press shop. Thus, the time used for changing the dies to produce batches of a different car body part need to be kept to a minimum. (Kropik, 2009)

The context in which the integrated investing method is applied is a brownfield investment in form of a retrofit measure of an old transfer press. Figure 53 represents an exemplary illustration of a transfer press with four work sequences. The previously cut steel sheet is fed into the transfer press and lubricated with drawing oil to avoid cracks and tears during the subsequent forming processes.

The positioning station ensures that the dimensions of the steel sheet are in-between the given parameters and that its position enables correct grabbing by the first transfer robot. During four consecutive work sequences, the steel sheet is transferred by robots from one form-giving dice to the next to finally be placed on the output conveyor belt. The pressed car body part is stacked with the other parts of the same batch to finally be transferred to the interim storage.

Figure 53: Illustration of a transfer press with four work sequences



Source: According to Birkert et al., 2013:473

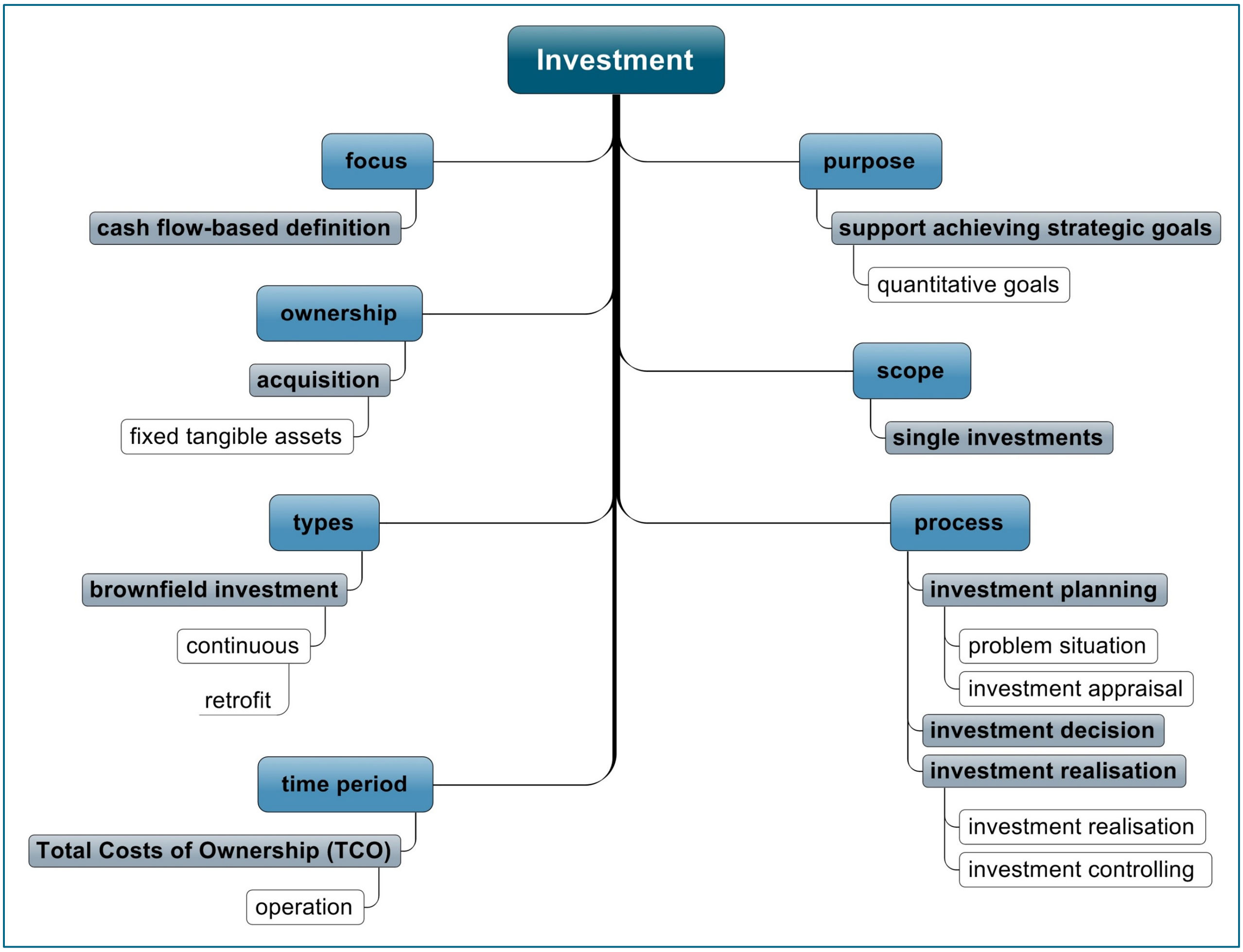
Description of the case along the investment process

The case study deals with a brownfield investment in form of a retrofit measure of an old transfer press. The transfer press, representing an acquired fixed tangible asset, supports the strategic goal by ensuring to achieve the targeted production output. Regarding the time period, this case study focuses on the operation phase within the TCO-characteristics. Hence, dismantling and disposal of the complete transfer press at the end of its useful lifetime is excluded in the context of this case study.

Since the investment is already realised, all phases of the investment process are taken under consideration within this case study. However, since only one supplier is able to offer the competence for the needed retrofit measure, there is no research for alternatives within the investment planning phase.

The following figure provides an overview over the attributes and characteristics of the investment within this case study:

Figure 54: Overview of attributes and characteristics of the investment within this case study



Source: Own illustration

Problem situation

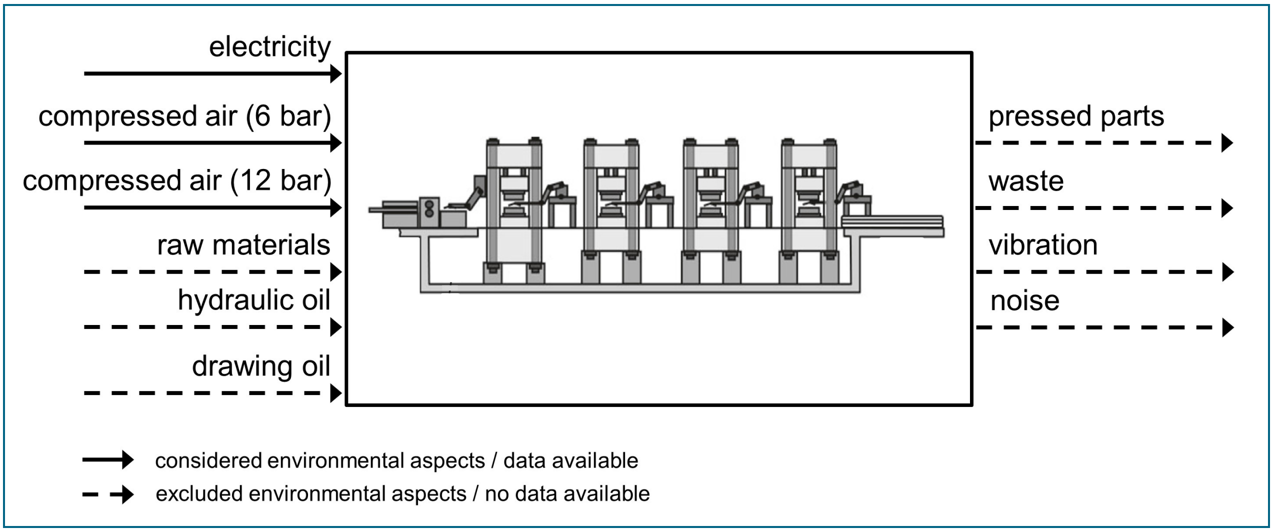
The start of the investment process is represented by the problem situation that the transfer press was originally installed in the year 1988. Besides the typical age-caused fatigue symptoms, the problem for the maintenance department was the expiring service of spare part delivery by the manufacturer of the transfer press. Hence, the broken parts of the press had to be sent to the press manufacturer, which would try to imitate or reconstruct the part of the press and send it back to the automotive manufacturer. As a consequence, the transfer press would not be able to run for several days causing a delay of car body parts production. In extreme cases, the production flow within the subsequent body shop would be at risk due to expiring batches of car body parts in the interim storage. Therefore, the management of the press shop decided to retrofit the transfer press with a new powertrain ensuring new long-term spare part delivery service.

The integrated investing method suggests to depict the current situation in form of a flow model and to determine the amount of eco-points caused by current operations. With regard to the resource and emission flows, the following flows occur with the operation of a transfer press:

- electricity consumption
- compressed air (6 bar and 12 bar) consumption
- consumption of oil and lubrication
- waste production
- noise and vibrations

While electricity and compressed air consumption is measured via metering points, the consumption of oil and lubrication is not systematically measured and thus cannot be used as a basis for the current situation. The production of waste consists out of scrap metal due to the material utilisation rate of about 45 percent (Volkswagen, 2015b). Since the scrap metal of all presses in the press shop is centrally collected, compressed and returned to the metal sheet supplier, it is not systematically measured per press and therefore is not part of this case study as well. Hence, the following flow model depicts the considered material and emission flows of the transfer press within a flow model.

Figure 55: Flow model of the resource flows of the transfer press considered for the current situation



Source: Own illustration in combination with Birckert et al., 2013

Due to confidentiality restrictions of Volkswagen, the annual resource flows and the amount of eco-points was multiplied with the same factor which is only known to the author of this dissertation. The adjusted annual resource flows of the current situation are expressed in Table 47.

In addition, the table below comprises the corresponding environmental impact expressed in eco-points. A detailed calculation of these eco-points can be found in appendix 3, which represents an exemplary environmental impact assessment on basis of the ESM.

Table 47: Overview of resource flows and eco-points of the current situation

Resource flow	Consumption	Eco-points
Electricity	8,057.163 kWh/a	172.36 eco-points
Compressed air (6 bar)	10,531,655 Nm^3/a	25.23 eco-points
Compressed air (12 bar)	96,970 Nm^3/a	0.30 eco-points
Sum		**197.89 eco-points**

Source: Own calculations on the basis of Volkswagen, 2014c [data adjusted according to secret factor]

After the determination of the current situation, the integrated investing method suggests to describe the desired situation. This description should also be expressed in form of a flow model and thus should include targeted resource and emission flows as well as a targeted amount of eco-points. However, the focus of the problem situation is to guarantee constant operation of the transfer press without any unnecessary downtimes. Due to the origin of the problem situation, the desired situation does not include any resource or emission flow-related target formulation. Besides the primary goal of ensuring problem-free production, a secondary goal of the retrofit measure is to reduce resource consumption. Nevertheless, there is no formulated and quantifiable target of the desired reduction in resource consumption.

Search for investment objects

The retrofit measure in form of exchanging the power train of the transfer press is planned to be examined in cooperation with the manufacturing company of the transfer press. Hence, there is no search for alternative investment objects conducted. One possible alternative scenario is to replace the complete transfer press by a new transfer press. Yet, due to the vast amount of expected capital expenditure needed to examine this scenario in comparison to the capital expenditure needed for the retrofit measure, this scenario was neglected in a very early stage.

Nonetheless, the integrated investing method suggests forecasting resource and emission flows of the investment object. In a project paper, the planning department forecasts a reduction in energy consumption of three percent. As a consequence, the consumption of electricity and compressed air can be forecasted by deducting three percent from the consumption levels of the actual situation. The following table summarises the forecasted consumption levels as well as their corresponding environmental impacts in form of the eco-factors:

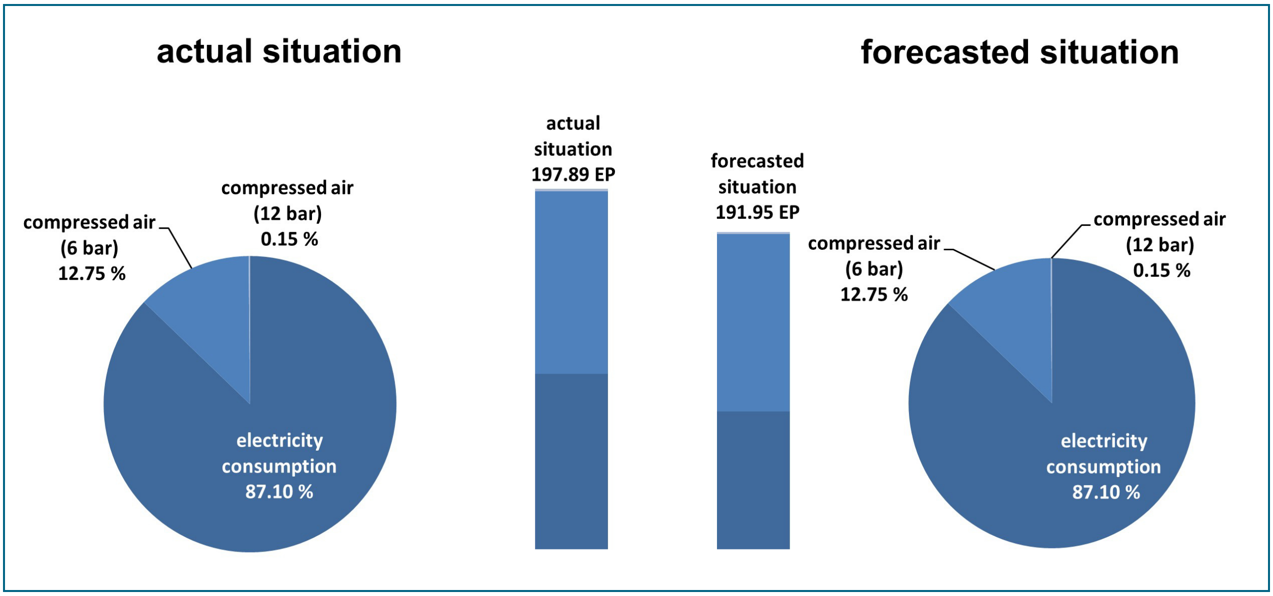
Table 48: Forecast of resource flows and eco-points of the retrofit measure

Resource flow	Consumption	Eco-points
Electricity	7,815.449 kWh/a	167.18 eco-points
Compressed air (6 bar)	10,215,706 Nm^3/a	24.48 eco-points
Compressed air (12 bar)	94,061 Nm^3/a	0.28 eco-points
Sum		**191.94 eco-points**

Source: Own calculations on the basis of Volkswagen, 2014c [data adjusted according to secret factor]

The integrated investing method suggests visualising and comparing the environmental impact of the competing investment objects in form of pie and bar charts. Due to an absence of competing investment objects, the environmental impact of the actual situation can be visualised and compared to the forecasted situation. Figure 56 provides such a visualisation and additionally reveals that the proportions as well as the total amount of eco-points only slightly changes due to the underlying assumption of three percent difference in energy consumption.

Figure 56: Comparison of environmental impacts of the actual and forecasted situation



Source: Own illustration

Investment appraisal

The investment appraisal step within the integrated investing method contains the conventional financial indicators (such as PBP, ROI or NPV) but also adds an environmental perspective with the indicators measuring the total environmental impact in eco-points and the relation of the saved eco-points to the capital expenditure and operating expenditure.

The capital expenditure could be forecasted based on the offer of the press manufacturer as well as the expected decrease in electricity consumption which was combined with a decrease in operating expenditure. While there was no forecast of the financial indicators PBP, ROI and NPV, the forecasted environmental impact could be calculated based on the expected reduction in electricity consumption. Due to the forecasted amounts of expected capital and operating expenditure, the eco-efficiency indicators could be forecasted as well.

The following table summarises the investment appraisal of the retrofit measure according to the integrated investing method.

Table 49: Investment appraisal of the retrofit measure of a transfer press

Indicator	Retrofit measure
Total capital expenditure (in €)	25,803,800
Annual operating expenditure (in €)	815,984
Payback period (in years)	-
Return on investment (in percent)	-
Net present value (in €)	-
Total environmental impact (in eco-points)	191.95
Reduced environmental impact (in eco-points)	5.95
Investment eco-efficiency (in €/saved eco-point)	4,346,750
Operating eco-efficiency (in €/saved eco-point)	137,455
Operating eco-efficiency relation	- 0.06

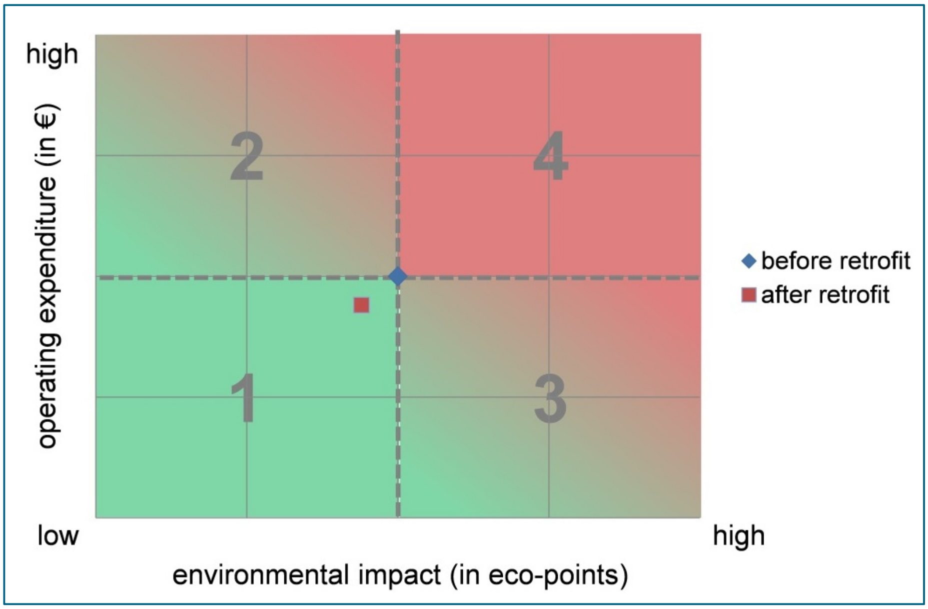
Source: Own calculations on the basis of Volkswagen, 2014c and Grochowski, 2015 [data adjusted according to secret factor]

Investment decision

The integrated investing method suggests mapping the alternatives of the investment appraisal on a 2x2-matrix in which the environmental and financial perspectives of the investment objects are depicted. The middle of this map is represented by a target value which consists out of the capital expenditure budget and the expected amount of reduced eco-points for the year. The intention behind the map is to provide an overview to the decision-maker and thus to support informed decision-making. However, within this case study, no targeted amount of reduced environmental impact and the targeted capital investment budget could be determined.

Nevertheless, a map can still be created with slight adjustments. In the context of this case study, the relation of the operating expenditure and the environmental impact of the press under current operation and under forecasted operation after the retrofit measure can be compared and illustrated (see Figure 57).

Figure 57: Mapping the operational expenditure and environmental impact before and after the retrofit



Source: Own illustration

Although this case study does not comprise any alternatives, the decision-maker is still faced with the decision of examining the investment or taking the risk of production downtimes and not investing in the retrofit measure. This could be a viable option in case the downtime either could be compensated by higher interim stocks, outsourcing the concerned batches to an external contract manufacturer, or by investing the capital expenditure in a different investment object which is not related to this case study.

However, the executive management finally decided to conduct the investment in the retrofit measure of the transfer press, since the risk of production downtimes could not be adequately compensated and therefore needed to be avoided for future production plans. Nevertheless, an analysis calculating the opportunity costs of not investing was not available.

Investment realisation

Regarding the realisation phase of the investment process, the integrated investing method suggests to install metering points that measure the resource and emission flows of the investment. In this case study, metering points for the transfer press already exist and are situated in front of the transfer press so that the measured quantities can only be allocated to the transfer press. While the electricity and compressed air consumption could already be measured for the complete transfer press beforehand, one option would have been to install additional metering points within the transfer press in order to monitor the consumption of the specific work sequences. Nonetheless, due to the fact that this transfer press runs with one power train it was decided against an installation of additional metering points.

Hence, the suggested coherence test with the flow model as well as the implementation in the IT-infrastructure does not need to be verified within this case study. In addition, a record of delivery was not necessary to be signed by the supplying company since there is no complete product delivered but rather an existing product retrofitted.

Investment controlling

The investment controlling phase intends to compare forecasted figures of the investment planning phase with actual figures after realisation of the investment. In addition, the underlying reasons for any deviations are intended to be determined and its implications or lessons learned for upcoming investment processes. Since the electricity and compressed air consumption of the transfer press could be measured via metering points before and after realisation of the retrofit, this data represents a valuable basis for the investment controlling phase. The following table compares the consumption before the investment, the forecasted data of the planning phase and the actual data after realisation.

It is important to mention, that this comparison is based on several assumptions providing the basis for a fair comparison. Therefore, the actually measured resource flows are recorded over a comparable time period, with a comparable utilisation rate and while pressing the exact same car body part. These figures were measured, analysed and extrapolated by the technical planning department in order to forecast the annual resource consumption figures.

Table 50: Comparison of forecasted energy consumption with consumption before and after realisation

Resource flow	Before	Forecast	After
Electricity (in kWh/a)	8,057.163	7,815.449	7,631,359
Compressed air (6 bar in Nm^3/a)	10,531,655	10,215,706	9,159,353
Compressed air (12 bar in Nm^3/a)	96,970	94,061	108,002
Environmental impact (in eco-points/a)	197.89	191.95	185.52

Source: Own calculation and Volkswagen, 2014c [data adjusted according to secret factor]

With regard to electricity consumption, the consumption after realisation of the retrofit even surpassed the projection of the investment planning phase. While the projection forecasted an electricity reduction of three percent, the actual reduction after realisation is about 5.28 percent. In addition, the consumption of compressed air (6 bar and 12 bar) was also forecasted with a decrease of three percent while the actual consumption of compressed air (6 bar) was lower than expected with a decrease of about 13.03 percent. In contrast to that, the consumption of compressed air (12 bar) increased by 11.37 percent. The maintenance department could not identify the reasons for this unexpected increase. Nevertheless, the total environmental impact could be decreased, even below the projection with a final reduction of 6.25 percent. After identifying the deviations in resource and emissions flows, the integrated investing method also advises to control the originally projected investment appraisal data with the actual data after realisation.

This comparison is depicted in the following table:

Table 51: Comparison of investment appraisal data and actual data

Indicator	Investment appraisal	After realisation
Total capital expenditure (in €)	25,803,800	25,803,800
Annual operating expenditure (in €)	815,984	788,651
Payback period (in years)	-	-
Return on investment (in %)	-	-
Net present value (in €)	-	-
Total environmental impact (in eco-points)	191.95	185.52
Reduced environmental impact (in eco-points)	5.94	12.36
Investment eco-efficiency (in €/saved eco-point)	4,346,750	2,087,111
Operating eco-efficiency (in €/saved eco-point)	137,445	63,789
Operating eco-efficiency relation	- 0.06	- 0.12

Source: Own calculation based on Volkswagen, 2014c and Grochowski, 2015 [data adjusted according to secret factor]

The table above shows that actual figures have performed better than projected figures of the investment appraisal. The reasons for the identified deviations might be the prudence of original forecasts or unexpected efficiency gains which could not be quantified beforehand.

An additional question which the integrated investing method recommends to ask in the context of the controlling phase is the question of whether the original problem could be solved and if the desired ideal situation could be achieved. The main intention of the retrofit measure was to avoid the risk of downtimes which was achieved after the realisation. In addition, a secondary goal was to reduce resource and emission flows. This goal was achieved as well, although the consumption of compressed air (12 bar) increased, which will be part of a further analysis by the maintenance department.

5.3.3. New construction of a body shop

This case study intends to provide answers to the research question of how to successfully apply the integrated investing method into business practice. Therefore, the integrated investing method is applied based in a real-life investment case to identify possible problems and limitations during implementation.

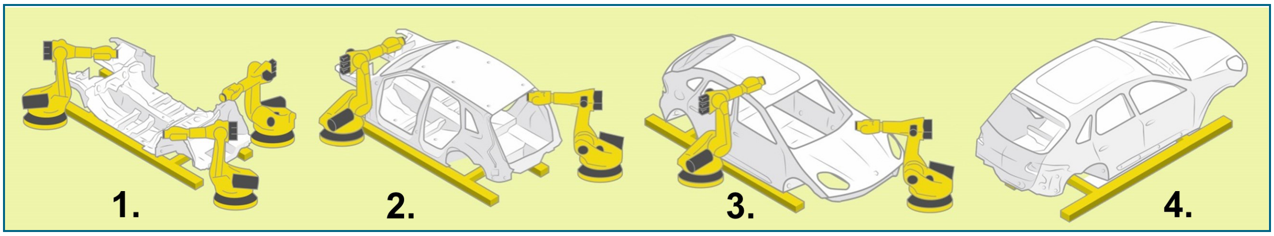
Context of the case

The body shop is situated after the press shop and thus mostly represents the second process within an automobile manufacturer's production line. After the different body parts were formed within the press shop and stored in batches within the interim storage, they are transported to the body shop in which they are put together to finally form the car body.

The body shop is characterised by a high degree of automation. Therefore, strict deviation tolerances intend to avoid problems within subsequent processes such as the assembly of the chassis or the interior within the final assembly process. The body shop is structured in cells which are represented by a group of robots producing components of the car body. These cells are structured in form of a ‘fishbone’, in which the central assembly line transports the final car body which is assembled by the components from the neighbouring cells. (Kropik, 2009)

The main assembly process within the body shop can roughly be separated in four different steps. The first step of the central assembly line represents the construction of the underbody which is assembled by the front- and back-end underbody as well as the wheel cases. This step contains several measuring points in which the right geometry is assured within several adjustment processes. The second step comprises the assembly of inner and outer side panels as well as the roof. Within the subsequent step, trunk lid, bonnet and doors are assembled before the car body has to pass the final quality control point of the body shop (see Figure 58). (Birkert *et al.*, 2013)

Figure 58: Rough overview of main assembly process within the body shop



Source: Porsche AG, 2015

The cells are mainly differentiated in devices measuring the geometry of the component or car body and welding devices. While there are single welding points applied within the geometry cells, the welding cells intend to apply the remaining welding points or welding seams. Several welding methods are applied within the body shop depending on the car body part, the materials which are joined together as well as the order of the different materials. (Birkert *et al.*, 2013)

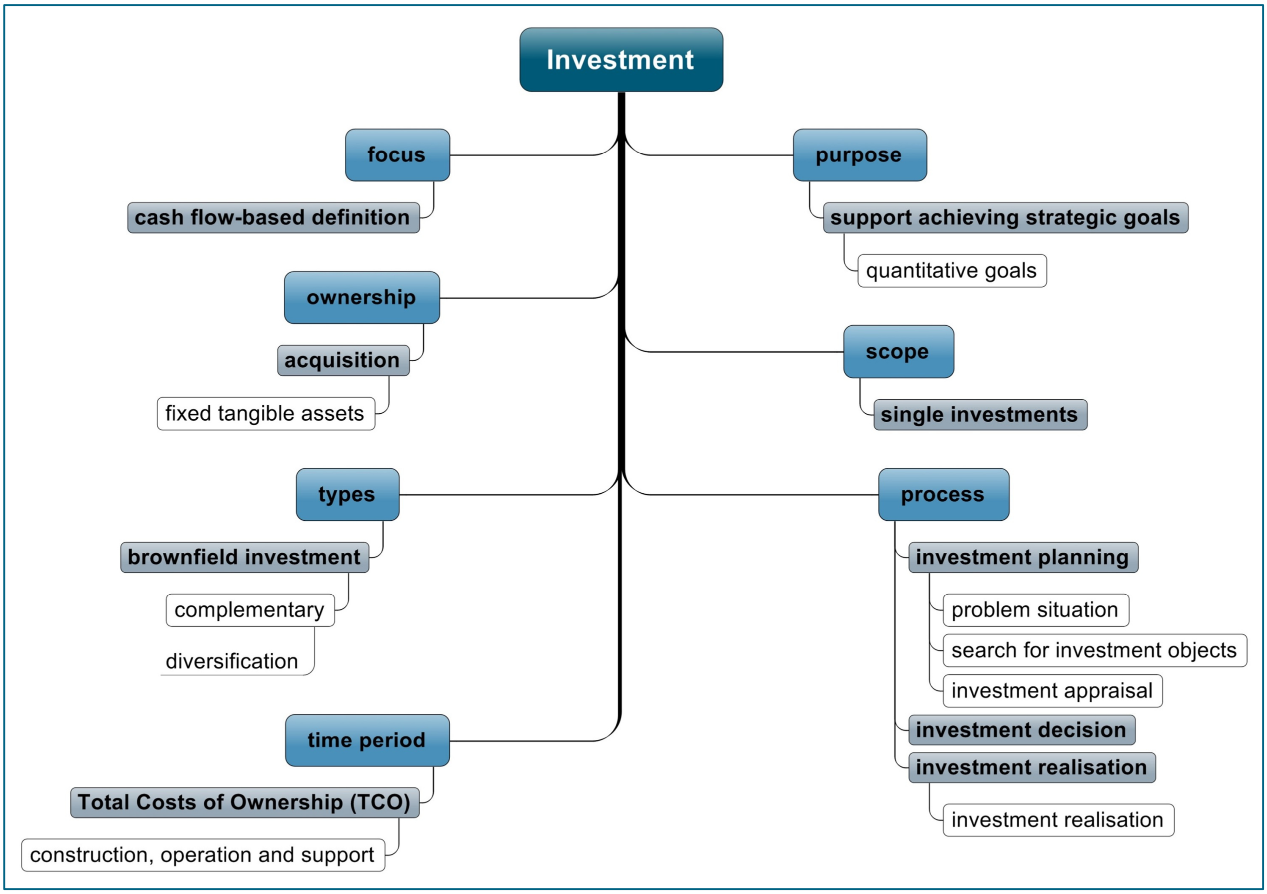
Description of the case along the investment process

The case study deals with a brownfield investment in which an old body shop was substituted by a new body shop. Since the investment is recently realised, all phases of the investment process are taken under consideration within this case study, except the investment controlling phase due to a lack of measured data. However, the time period is limited to the construction, operation and support which thus excludes the phases of dismantling and disposal.

The investment aims to support the strategic goals by ensuring future production capacity and by enabling the production of various future car models which all base on the same platform. Hence, the brownfield investment is characterised as complementary investment intending to offer advanced diversification of produced models.

The following figure provides an overview of the attributes and characteristics within this case study:

Figure 59: Overview of attributes and characteristics of the investment within this case study



Source: Own illustration

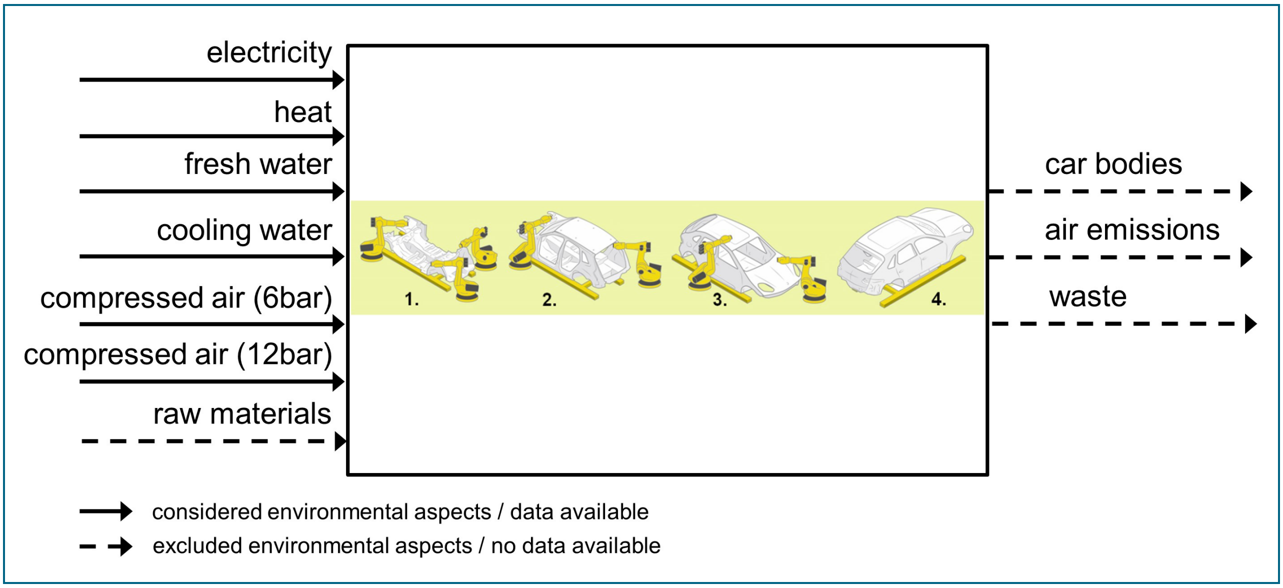
Problem situation

The upcoming introduction of a new car model raised the necessity for building a new body shop. Changes in car layouts such as updates of car models involve only minor adjustments in car body production such as changing grabbing tools or slight changes in motion sequences of robots. However, the new car model in this case study involved the implementation of a new platform (the modular transverse matrix) that was introduced within the Volkswagen Group and thus required radical adjustments of the production layout. (Volkswagen, 2015b) Since the body shop of the production site of this case study was already fully depreciated, the executive management decided to build a completely new body shop.

The integrated investing method suggests depicting the resource and emission flows of the current situation within a flow model. The resource flows under consideration within this case study comprise electricity consumption, heat consumption, fresh water and cooling water consumption as well as consumption of compressed air (6 bar and 12 bar). In addition, the operation of a body shop also involves air emissions as well as wastes. Nevertheless, both emission flows cannot be measured automatically due to missing alternative documentation. These emission flows are not considered within this case study.

The following figure illustrates the resource and emission flows of the body shop of this case study within a flow model.

Figure 60: Flow model of the resource flows of the body shop considered for the current situation



Source: Own illustration in combination with Porsche AG, 2015

In addition to this illustration, the integrated investing method advises quantifying and measuring the resource and emission flows of the current situation as well as calculating the associated eco-points. The consumption of the resources as well as the associated eco-points are summarised in Table 52. Due to confidentiality reasons of the Volkswagen Group, the values in the table below are adjusted to a secret factor which is only known to the author of this thesis.

Table 52: Overview of resource flows and eco-points of the current situation

Resource flow	Consumption	Eco-points
Electricity (in MWh/a)	412,436.48	12,645.71 eco-points
Heat (in MWh/a)	313,242.52	3,508.44 eco-points
Fresh water (in m^3/a)	381,601.14	8.64 eco-points
Cooling water (in m^3/a)	14,887,754.80	336.91 eco-points
Compressed air (6 bar) (in Nm^3/a)	182,578,538.20	626.98 eco-points
Compressed air (12 bar) (in Nm^3/a)	128,794,249.86	556.80 eco-points
Sum		**17,683.48 eco-points**

Source: Own calculations on the basis of Hillers, 2015a [data adjusted according to secret factor]

Unlike other investment cases with the same problem situation, in this case the management decided to additionally build a new production hall. This decision in advance enabled additional opportunities regarding the desired situation. Hence, the desired situation comprised the ability to meet the demands of the new modular transfer matrix but also the aim to radically decrease energy consumption. However, for the latter aim, no quantified target value was set.

Search for investment objects

The unit of analysis is defined as one piece of key-ready body shop. Nevertheless, this body shop consists out of many components such as the production hall, media supply infrastructure, robots and conveyor technologies, etc. which are supplied by various companies. Hence, the search for competing investment alternatives cannot be depicted in this case study in detail.

Nevertheless, the construction of the new body shop was summarised and internally reported as one project, enabling to provide a forecast of the expected resource and emission flows as well as operating and capital expenditure.

With regard to the resource and emission flows, the construction of the new production hall contained a combined cooling and heating system that is based on geothermal energy. Hence, before the construction of the hall, about 5,000 piles were drilled and rammed into the ground. These piles contain water pipes enabling fresh water to circulate through the piles and thus adjusting its temperature to the ground temperature. As a consequence, the welding robots of the body shop can be cooled by this water cycle, while additionally enabling to heat the production hall in the winter.

As a consequence of this combined cooling and heating system based on geothermal energy, there is decreased supply of technical heat from gas. While the need for cooling water increases due to the geothermal energy system, the fresh water consumption is expected to keep constant since this comprises mostly sanitary water supply. Furthermore, the planning department of the new body shop aimed to operate future body shop processes without 12 bar compressed air so that only 6 bar compressed air is needed. Finally, the resource and emission flows of the new body shop are forecasted and compared to the old body shop (see Table 53). The values within the table below are adjusted to a secret factor that is only known to the author of this thesis due to the confidentiality requirements of the Volkswagen Group.

Table 53: Comparison of resource and emission flows of the new body shop with the old body shop

Resource flow	Old body shop	New body shop	Difference
Electricity (in MWh/a)	488,010	238,364	- 51.16 %
Heat (in MWh/a)	370,640	109,966	- 70,33%
Fresh water (in m^3/a)	451,525	451,525	0,00 %
Cooling water (in m^3/a)	17,615,745	23,537,250	+ 33.61 %
Compressed air (6 bar in Nm^3/a)	216,033,171	196,143,750	- 9.21 %
Compressed air (12 bar in Nm^3/a)	152,394,146	-	- 100.00 %

Source: Own calculations based on Hillers, 2015a and Hillers, 2015b [data adjusted according to secret factor]

Besides the forecast of resource and emission flows, the integrated investing method suggests calculating the expected amount of eco-points. While Table 52 reveals that the old body shop caused an environmental impact of 17,683 eco-points, the following table summarises the forecasted environmental impact of the new body shop in form of eco-points:

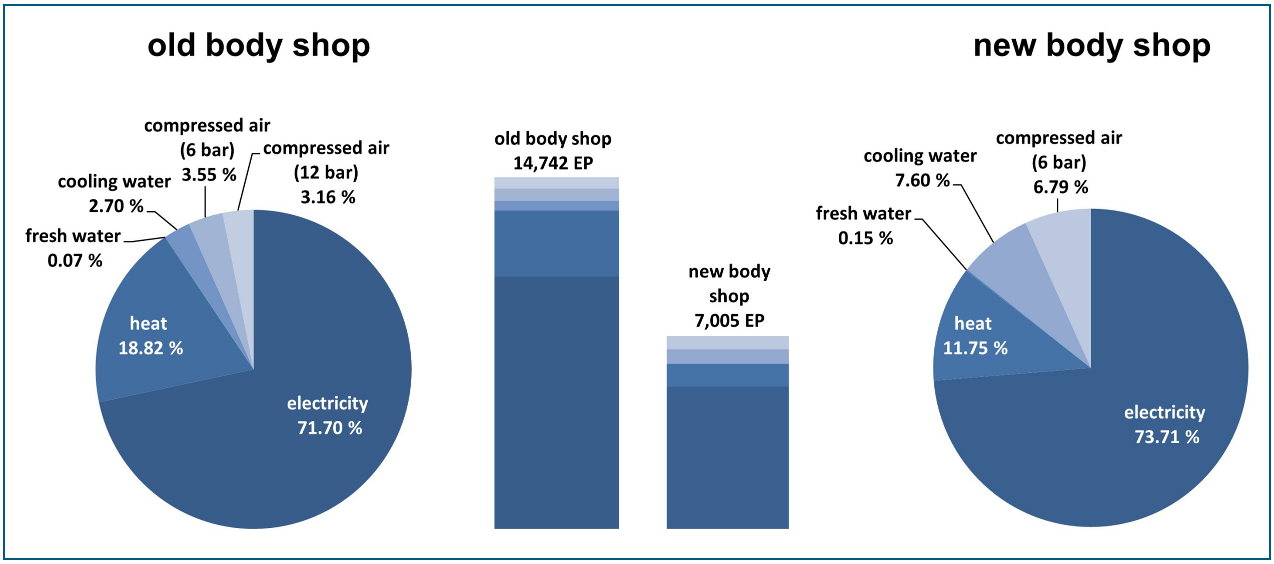
Table 54: Forecast of resource flows and eco-points of the new body shop

Resource flow	Consumption	Eco-points
Electricity (in MWh/a)	238,364	5,163 eco-points
Heat (in MWh/a)	109,966	823 eco-points
Fresh water (in m^3/a)	451,525	10 eco-points
Cooling water (in m^3/a)	23,537,250	533 eco-points
Compressed air (6 bar) (in Nm^3/a)	196,143,750	476 eco-points
Sum		**7,005 eco-points**

Source: Own calculations on the basis of Hillers, 2015b [data adjusted according to secret factor]

In addition, the integrated investing method advises to compare the total amounts of eco-points as well as their proportions of the various competing investment alternatives. Since, this case study does not involve an alternative investment object, the total environmental impact of the new body shop is compared with the total environmental impact of the old body shop (see Figure 61). When comparing the proportions within the eco-points of the old and new body shop, it is noticeable that the share of electricity consumption increases as well as compressed air (6 bar) and cooling water. This development is caused by the lack of compressed air (12 bar) within the new body shop as well as decrease for heat and cooling water due to the use of geothermal energy.

Figure 61: Comparison of environmental impacts of new and old body shop



Source: Own illustration

Investment appraisal

Due to restricted access to financial data, it was only possible to retrieve the resource and emission flow data as well as the amounts of capital and operating expenditure. Hence, there is no calculation of payback period, return on investment or net present value provided within this case study.

Due to confidentiality reasons, the data in the table below regarding capital expenditure and operating expenditure were adjusted according to a secret value.

Table 55: Investment appraisal of the new body shop

Indicator	New body shop
Total capital expenditure (in €)	3,004,596,613
Annual operating expenditure (in €)	71,105,635
Payback period (in years)	-
Return on investment (in percent)	-
Net present value (in €)	-
Total environmental impact (in eco-points)	7,005
Reduced environmental impact (in eco-points)	7,738
Investment eco-efficiency (in €/saved eco-point)	388,284
Operating eco-efficiency (in €/saved eco-point)	3,934
Operating eco-efficiency relation	- 1.10

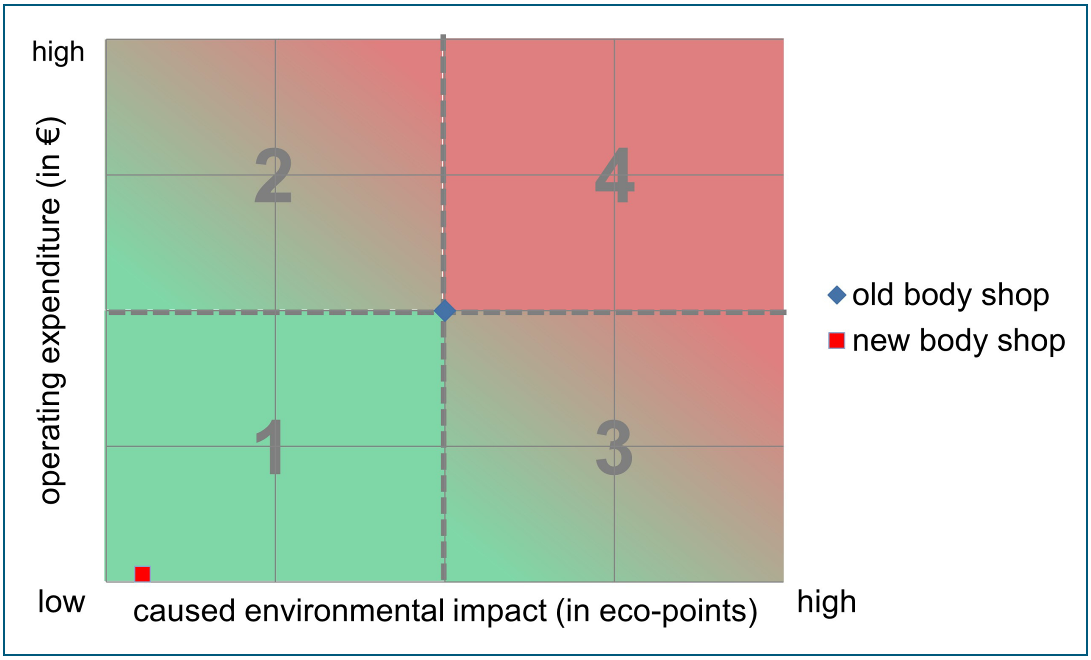
Source: Own calculations based on Hillers, 2015a, Hillers, 2015b and Steffen, 2015 [data adjusted according to secret factor]

Investment decision

The integrated investing method introduces the idea of mapping the alternatives on a 2x2-matrix where the y-axis maps the financial perspective and the x-axis represents the environmental perspectives. The middle of the matrix is based on the targeted budget and the amount of targeted reduced environmental impact in form of eco-points. However, within this case study, no targeted amount of reduced environmental impact and the targeted capital investment budget could be determined.

Nevertheless, financial and environmental parameters of the new body shop can be mapped with the help of the financial and environmental parameters of the old body shop functioning as a reference point. Therefore, the map contains the amount of eco-points on the x-axis and the amount of operating expenditure on the y-axis. Hence the following figure depicts the financial and environmental performance of both body shops:

Figure 62: Mapping the operating expenditure and caused environmental impact of both body shops



Source: Own illustration

In addition to the map, the integrated investing method advises to rank the results of the investment appraisal in order to further clarify the relative advantageousness of the investment alternatives under consideration. After this step is examined for each available indicator, the sum of the rankings indicates the investment alternative with the highest relative advantageousness.

Nevertheless, due to the fact that there is no competing investment alternative, the advice of building a ranking in order to calculate a utility value is obsolete in the context of this case study. Due to the absence of alternatives, it was decided to invest in the new construction of the body shop. This absence of alternatives occurred due to the introduction of the new modular transverse matrix, which made an investment in a new body shop inevitable.

Investment realisation

During the construction of the new body shop, over 500 metering points were installed with the aim to provide a detail analysis of the relevant energy consumers. These metering points record the consumption of electrical energy, heat, cooling water as well as compressed air. However, the calibration and the implementation of the metering points is still in progress and is expected to be finished after the start of production.

In addition, the comparison of actual measured data with originally projected data could not be executed so far since the production volume has not reached its maximum. Once, this maximum is reached, the resource and emission flow data can be recorded for an appropriate amount of time (for instance one month) in order to calculate a fair comparison.

5.3.4. New paint shop on a greenfield site

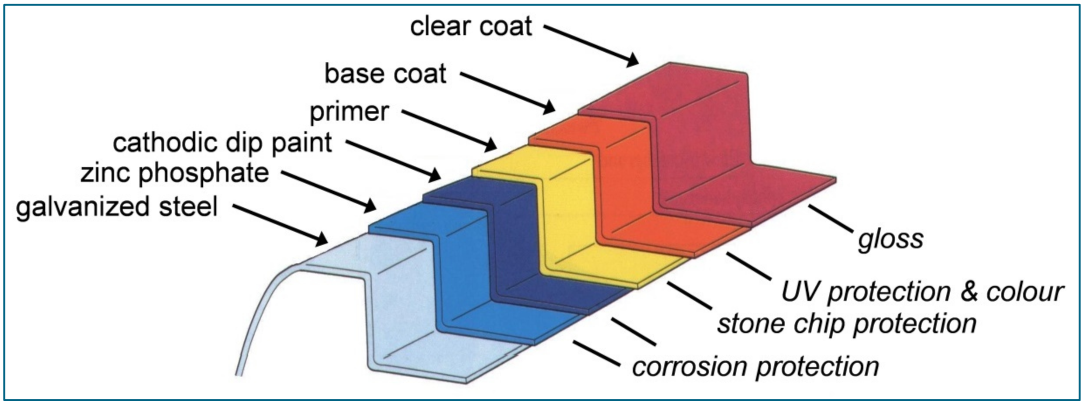
This case study intends to provide answers to the research question of how to successfully apply the integrated investing method into business practice. Therefore, the integrated investing method is applied based in a real-life investment case to identify possible problems and limitations during implementation.

Context of the case

The context in which the method is applied within this case study is the greenfield investment in a new paint shop for a new production site. According to Kropik (2009) the paint shop is the production step with the highest capital investment need. Due to its long-term operation, several models as well as model generations can be painted within one and the same paint shop.

The painted surface of a car consists out of five layers as illustrated in the following figure:

Figure 63: Layers within the painting process for a car



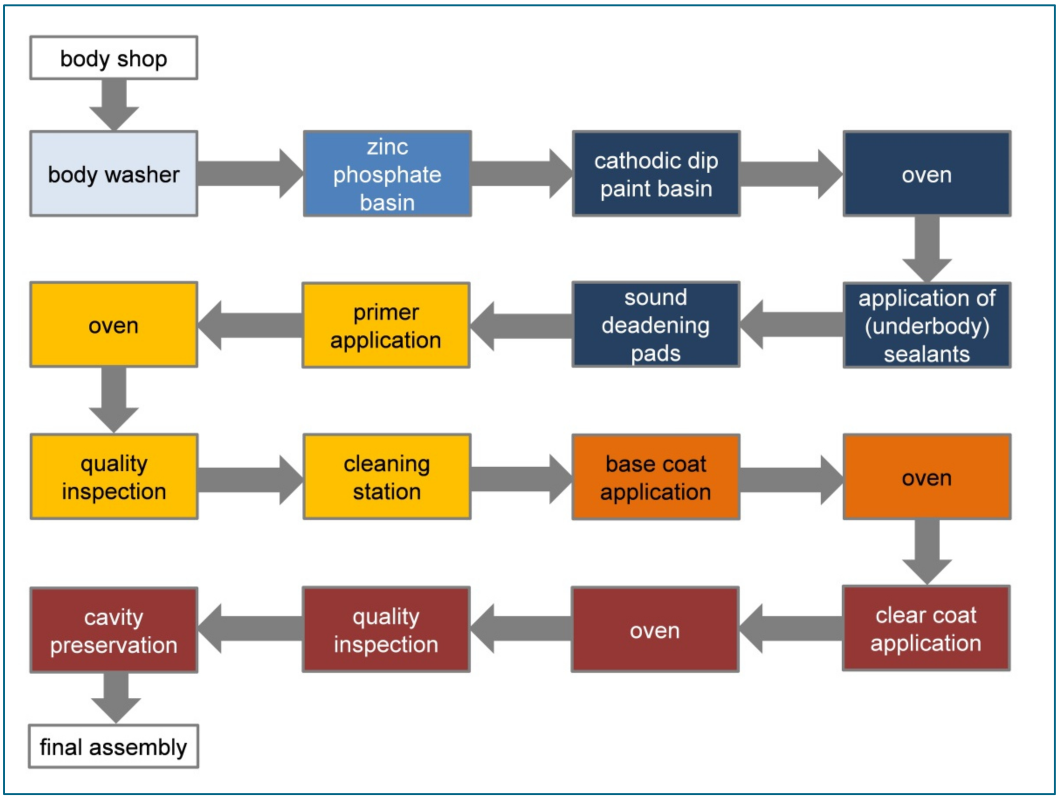
Source: Own illustration, according to Volkswagen AG, 2012d

While the first two layers aim to protect against corrosion, the third layer functions as stone chip protection layer as well as foundation for better adherence of the remaining two layers which provide the colour and the gloss.

In order to apply these five layers, a complex sequence of several processing steps is necessary, which is illustrated in Figure 64. The first step aims to clean the body and thus remove metal chips and oil remaining from the processing steps of the previous body shop. At the end of this first step, the first layer of zinc phosphate is applied as well via rolling and dipping the body through a basin. The same method is used to apply the second layer consisting out of the cathodic dip paint which is dried in an oven afterwards. Within the following steps, employees prepare for the application of the underbody sealant (UBS) and apply the sealing at doors, flaps and lids. In addition, the sound deadening pads are inserted and attached.

The following step comprises the application of the primer which is dried in an oven afterwards. Before the next layer can be applied, the body is checked for possible faults in appearance within quality inspection and is handed over to another cleaning station afterwards. After the cleaning station has removed dust or other particles from the body, the base coat is applied which provides the colour and the UV protection of the body. The base coat is dried in an oven before the clear coat is applied and dried in another oven. The performance of the applied layers is checked within a subsequent quality inspection step before the cavity preservation is examined by flooding the body with hot wax. After this final processing step, the painted body is handed over to the final assembly.

Figure 64: Simplified layout of paint shop processing steps



Source: According to Dürr AG, 2015 and Volkswagen, 2012d

The application of the layers as well as the high quality standards require a standardised process which are determined by strict processing parameters. Therefore, it is common that only one company supplies all elements of a paint shop. There are only few rivalling companies on the market providing key-ready paint shops, due to the low frequency of paint shop orders, the low amount of possible clients within the automotive industry and the high degree of specialisation.

Description of the case along the investment process

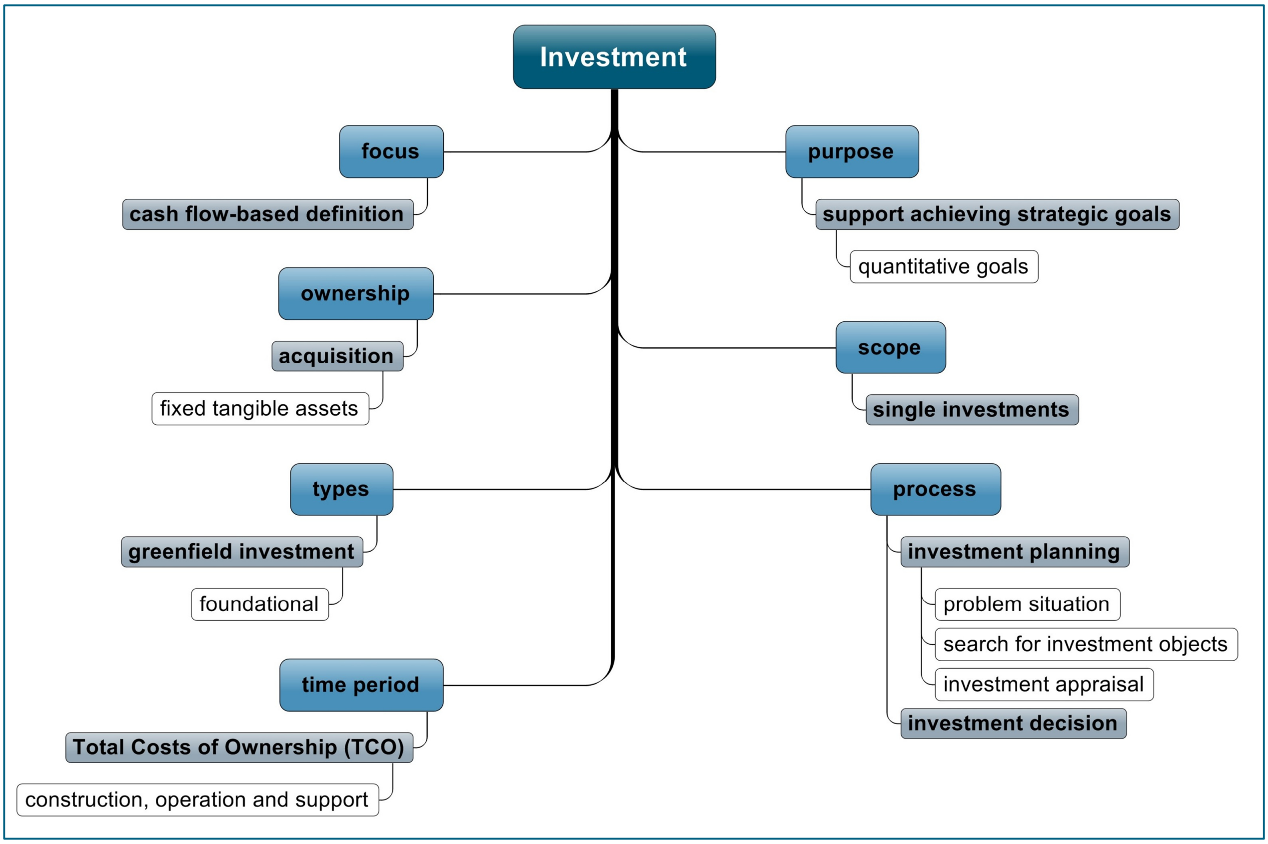
The case study deals with a greenfield investment for a new production site. This newly built site represents a foundational investment since an expiration of a joint production with a business partner necessitated the construction of a wholly-owned production site.

The process involves a company-owned planning department which plans and constructs the site. Once the site is turnkey-ready, it is handed over to the plant operator. The acquisition of this new fixed tangible asset is realised via inner-company transfer prices.

Since the site is currently under construction, the investment process cannot comprise all phases due to a lack of data and thus misses the phase of investment realisation. In addition, the time period under consideration comprises only the construction, operation and support phases.

The following figure provides an overview of the attributes and characteristics within this case study:

Figure 65: Overview of attributes and characteristics of the investment within this case study



Source: Own illustration

Problem situation

The starting point for the investment need originates from an expiring contract with a business partner. This contract contains the joint production of a vehicle which is labelled differently at the end of the production. Since the continuation of this contract is not a strategic option, the necessity of building a new production site also causes the need for investing in a new paint shop.

The method advises to sketch the current situation with the help of a flow model and to calculate the amount of eco-points currently produced. Within a subsequent step, the desired situation should be described, expressed in an amount of eco-points and visualised with the help of a flow model.

However, in this case, the procedure does not represent a helpful option since the actual production site cannot be compared to the newly built production site due to the lack of a joint production partner.

Nevertheless, the desired situation can be described with the aim to build a paint shop that causes an environmental impact that is as moderate as possible. Due to this aim, the paint shop needs to be built beyond the current state of the art. With the help of this requirement, the current state of the art can be quantified in form of a total amount of eco-points.

Search for investment objects

The processing steps as illustrated in Figure 64 are mainly the same at the offered paint shops on the market. Yet, the two main competitors on the market mainly differentiate within the processing steps of the base coat application and the clear coat application. This difference concerns the overspray which is bound in water that is filtered afterwards with one supplier, while its main competitor blows out the overspray with compressed air and binds it in rock flour. While the first process (i.e. binding overspray in water) represents a common state of the art process, the second option (i.e. binding overspray in rock flour) represents an innovation on the market.

The considered investment alternatives represent these two main differences and also take account for the fact that the market of key-ready paint shops is dominated by two suppliers. Hence, 'supplier a' offers a paint shop that binds overspray in water and 'supplier b' offers an innovative alternative that binds overspray in rock flour.

Both suppliers tailor their offers according to the same specification sheet that is written by the technical planning department of Volkswagen. Hence, the offers contain forecasts of the following parameters:

- Total capital expenditure
- Annual operating expenditure
- Annual resource and emission flows
  a. Electricity consumption
  b. Hot water consumption
  c. Cold water consumption
  d. Heat consumption
  e. Fresh water consumption
  f. Consumption of fully desalinated water
  g. Consumption of compressed air (6 bar)
  h. Waste water production
  i. Hazardous waste production
  j. Non-hazardous waste production

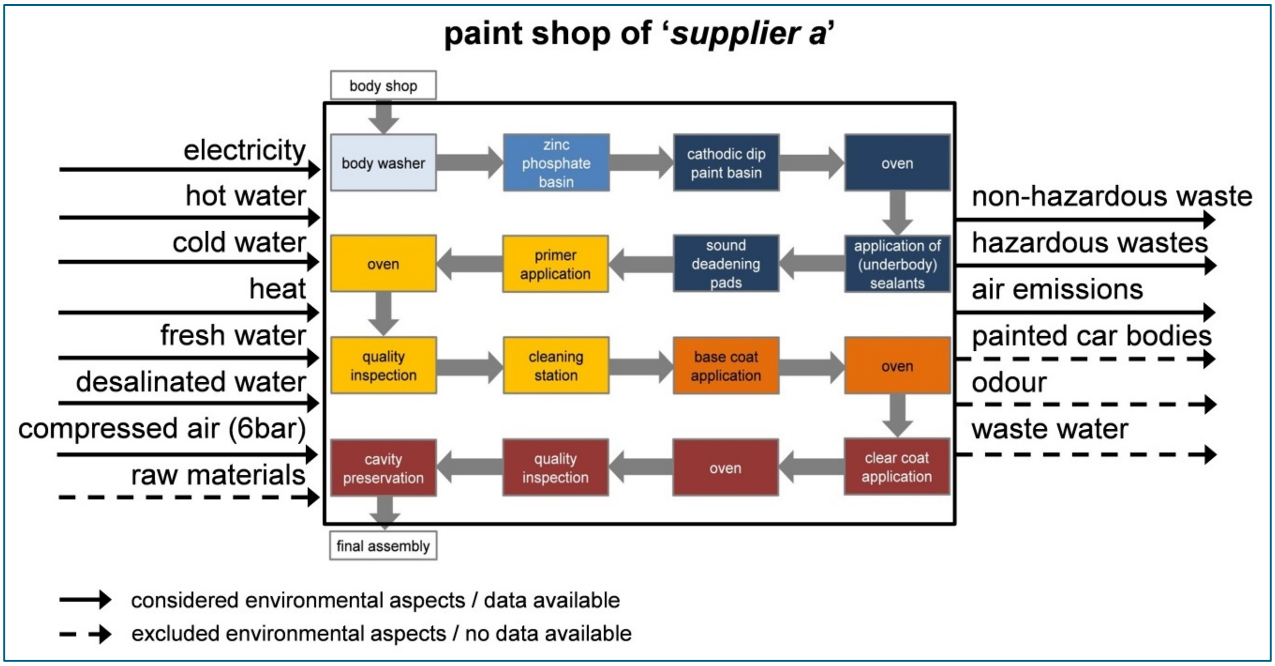
These projected flows are provided in tables that list the material and emission flows per processing step. In addition to these projections which are provided by the suppliers' offers, the environmental management department creates a forecast for emissions of volatile organic compounds (VOCs).

However, the emission projections are assumed to be equal for both suppliers since the projected amount of paint applied is the same in both offers.

In order to compare the alternatives, the integrated investing method advises to visualise the material and emission flows in a flow model. On the one hand, the data enables the visualisation of inputs and outputs for each production step. On the other hand, most of the process steps are similar for both offers. Hence, the differences regarding the base coat and clear coat application steps can be visualised within the flow models of total material and emission flows of both suppliers.

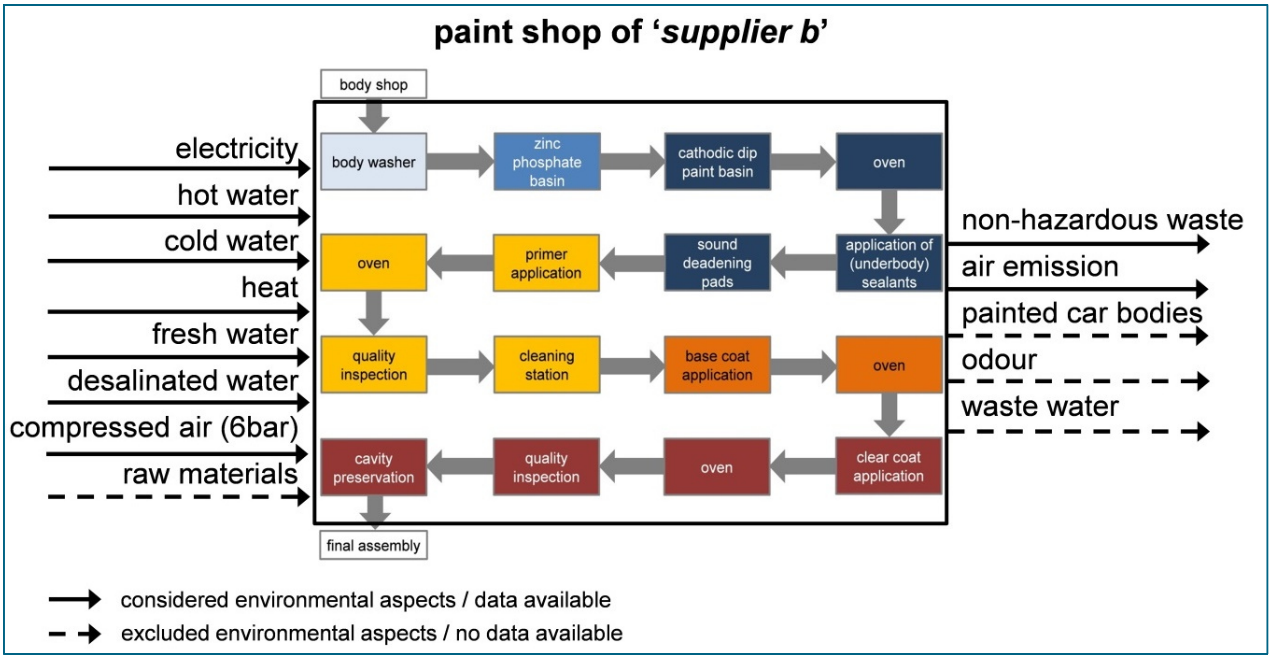
The following two figures compare the total resource and emission flows of both offers:

Figure 66: Flow model of the paint shop of 'supplier a'



Source: Own illustration according to Dürr AG, 2015; Volkswagen, 2012d and Gebler, 2014

Figure 67: Flow model of the paint shop of 'supplier b'



Source: Own illustration according to Dürr AG, 2015; Volkswagen, 2012d and Gebler, 2014

Due to confidentiality, real amounts of resource and emission flows cannot be provided within this dissertation. Therefore, the amounts were adjusted by a secret factor that is only known to the author of the thesis.

The following table lists and compares the resource and emission flows of the paint shops of both suppliers:

Table 56: Resource and emission flows of both paint shops

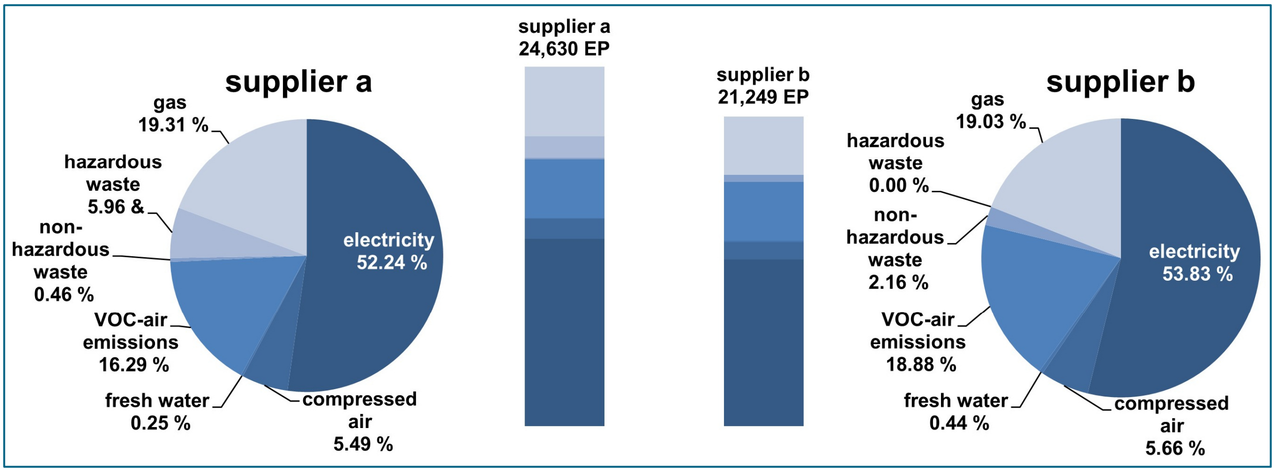
Resource or emission flows	Supplier a	Supplier b	Difference
Electricity consumption (in MWh/a)	405,553	389,341	- 04.00 %
Electricity for hot water provision (in MWh/a)	123,517	82,210	- 33,44 %
Electricity for cold water provision (in MWh/a)	64,207	56,520	- 11.97 %
Heat consumption (in MWh/a)	635,420	540,207	- 14.98 %
Consumption of desalinated water (in m^3/a)	1,023,783	1,869,220	+ 82.58 %
Fresh water consumption (in m^3/a)	1,399,682	1,790,916	+ 27.95 %
Consumption of compressed air (6 bar in Nm^3/a)	557,898,381	496,173,166	- 11.06 %
Hazardous waste (in t/a)	23,084	0	- 100.00 %
Non-hazardous waste (in t/a)	15,375	62,882	+ 308.98 %
VOC-air emissions (Kg/a)	2,719,795	2,719,795	00.00 %

Source: Own calculations based on Gebler, 2014 [data adjusted according to secret factor]

Table 53 reveals that the paint shop of 'supplier b' is more efficient regarding the inputs electricity, hot water, cold water, gas and compressed air while needing more fresh water and desalinated water. With regard to the output side of the flow model, main differences occur due to the overspray treatment process. Since 'supplier b' binds overspray in rock flour instead of water, the amount of non-hazardous waste (i.e. paint-contaminated rock flour) increases extremely on the one hand. On the other hand, however, there is no paint sludge which is categorised as hazardous waste.

With regard to the environmental impact of both offered paint shops, the total amount of eco-points of 'supplier a' is higher (24,630 eco-points) than the offered paint shop of 'supplier b' (21,249 eco-points). While the proportions of eco-points are nearly comparable with both suppliers, the main difference occurs from the absence of hazardous waste within the paint shop of 'supplier b'. In addition, the increased efficiency in most of the resources contributes to the lower environmental impact of 'supplier b'. The comparison of the environmental impacts of both offered paint shops is illustrated in the following figure:

Figure 68: Comparison of environmental impacts of both paint shops



Source: Own illustration

Investment appraisal

Due to confidentiality of sensitive data, the original figures provided by the two suppliers were adjusted according to the significant value which is only known to the author of this dissertation. However, the proportions keep the same which still enables to draw conclusions from the provided case study data.

Regarding the calculation of the important indicators analysing the investment, there is no access to the original data regarding the operating expenditure of the joint production site which is currently in place. Hence, there is no calculation of imputed cost savings possible that can serve as income or gains. As a consequence, the indicators, payback period, return on investment and net present value could not be calculated.

Hence, the following table summarises the result of the investment appraisal phase within the integrated investing method:

Table 57: Investment appraisal of both paint shops

Indicator	Supplier a	Supplier b
Total capital expenditure (in €)	1,862,058,000	1,743,500,000
Annual operating expenditure (in €)	210,440,672	194,493,677
Payback period (in years)	-	-
Return on investment (in percent)	-	-
Net present value (in €)	-	-
Total environmental impact (in eco-points)	24,630	21,249
Reduced environmental impact (in eco-points)	-	3,381
Investment eco-efficiency (in €/saved eco-point)	-	515,675
Operating eco-efficiency (in €/saved eco-point)	-	57,525
Investment eco-efficiency relation	-	- 0.20
Operating eco-efficiency relation	-	- 0.21

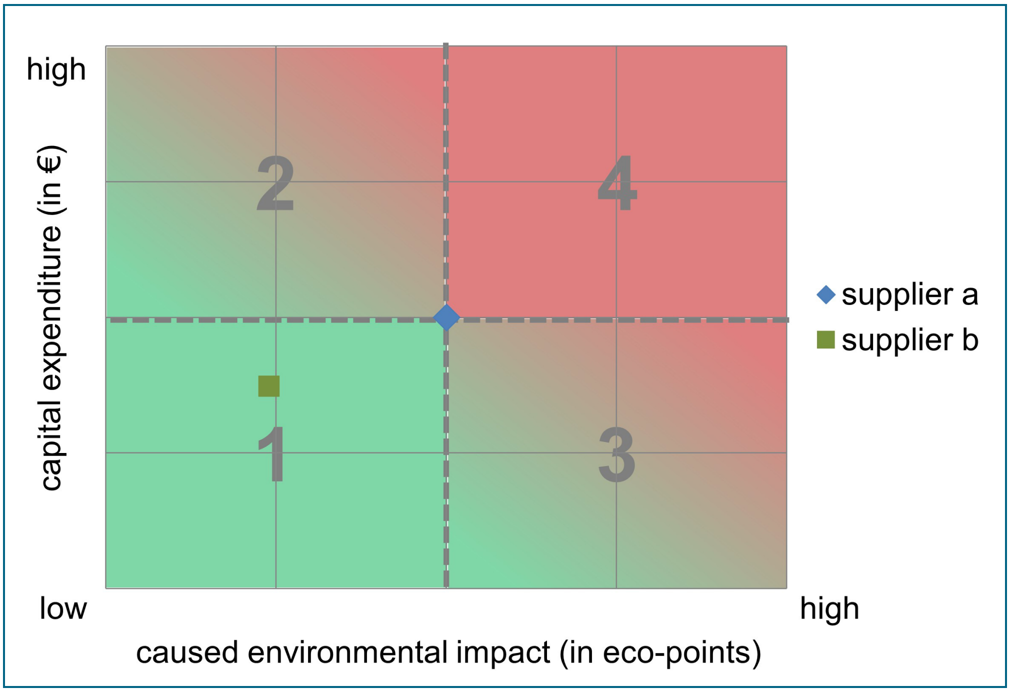
Source: Own calculations based on Gebler, 2014 [data adjusted according to secret factor]

Investment decision

The integrated investing method introduces the idea of mapping the alternatives on a 2x2-matrix where the y-axis maps the financial perspective and the x-axis represents the environmental perspectives. The middle of the matrix is based on the targeted budget and the amount of targeted reduced environmental impact in form of eco-points. However, within this case study, no targeted amount of reduced environmental impact and the targeted capital investment budget could be determined.

Nevertheless, a map can still be created with slight adjustments. Based on the assumption that the paint shop supplier offering the state of the art functions as target, there would be no rational reason for investing in more expensive paint shops with more environmental impact. Hence, the capital expenditure and the amount of eco-points of ‘supplier a’ build the coordinates for the target value which represents the middle of the map. The comparison of both suppliers is mapped in the following figure:

Figure 69: Mapping the capital expenditure and caused environmental impact of both suppliers



Source: Own illustration

In addition to the map, the integrated investing method advises to ranking the results of the investment appraisal in order to further clarify the relative advantageousness of the investment alternatives under consideration. After this step is examined for each available indicator, the sum of the rankings indicates the investment alternative with the highest relative advantageousness.

Due to the absence of the financial indicators PBP, ROI and NPV, the weightings have to be adjusted to represent an equal weighting between the financial and environmental perspective. In addition, the eco-efficiency perspective is not part of the ranking since the eco-efficiency indicators can only be generated for 'supplier b'. The following table provides the weightings in the context of this case study:

Table 58: Weightings in the context of this case study

Classification	Name	Weighting factor
Financial indicators	Capital expenditure (capex)	0.5
	Operational expenditure (opex)	0.5
Environmental indicators	Environmental impact	1

Source: Own representation

Finally, the total utility values of both competing investment object can be calculated:

Table 59: Total utility value of both paint shops

Name	Supplier a	Supplier b
Capital expenditure (capex)	#2 (1.0)	#1 (0.5)
Operational expenditure (opex)	#2 (1.0)	#1 (0.5)
Environmental impact	#2 (2.0)	#1 (1.0)
Total utility value	**#2 (4.0)**	**#1 (2.0)**

Source: Own calculation

Due to the fact that 'supplier b' is superior to 'supplier a' in financial and environmental perspectives, the total utility value provides the same result. As a conclusion, the management decided to invest in a paint shop of 'supplier b'.

5.3.5. Management and control of environmental goals for a business unit

This case study intends to provide answers to the research question of how to manage and control the achievement of strategic environmental goals of a company. Therefore, the case study is structured along the process of an environmental management control system.

Context of the case

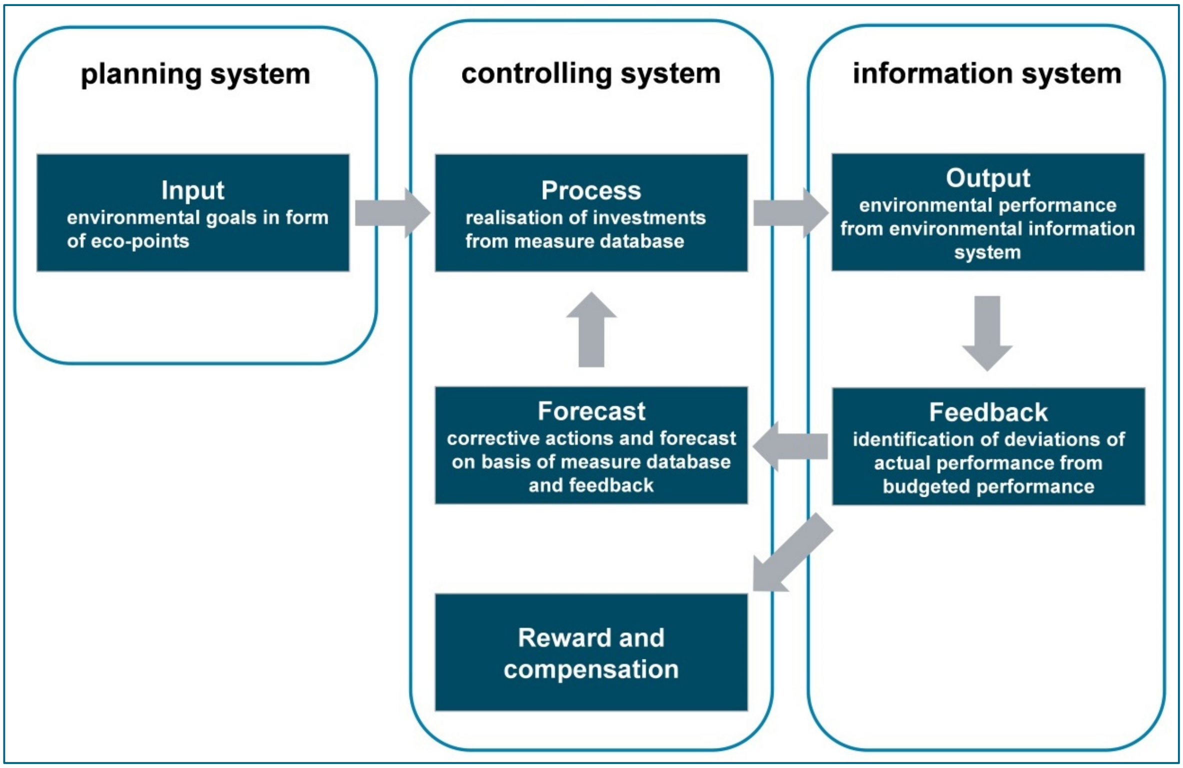
The context of this case study is represented by the business unit 'research and development', which is situated in Germany. With more than 10,000 employees, this business unit also examines technical development of systems and products. Hence, the over 50 buildings of the business unit comprise various machines, test stands, laboratories and offices.

Description of the case along the environmental management control system

The environmental management control system in context of this case study draws on the MCS as described within the definition of the unit of analysis. Hence, it assumes a process, represented by the realisation of investments within the time period under consideration. The input to this process is represented by environmental goals that can be expressed in a targeted amount of reduced eco-points within the same time period.

The output of this process in form of the environmental performance is compared to the expected or targeted environmental performance. On the basis of this comparison, the decision-maker has to induce corrective actions, if necessary, which impacts are forecasted as inputs on the process. In addition, it is assumed that there is a compensation system in place rewarding the decision-maker for achieving the given environmental goals. The following figure illustrates the management control system within this case study:

Figure 70: Environmental management control system in the context of this case study



Source: According to Schäffer, 2013; Zhang, 2014; Strauß and Zecher, 2013

Input in form of environmental goals

Since the business unit within this case study is not directly related to the production process, its environmental goal comprises an absolute reduction in energy and emissions of 25 percent till 2018, based on the values of 2010. While energy comprises electrical energy, technical heat and the use of fuel gas, the air emissions are summarised in CO_2-equivalents and calculated via emission factors, based on the corresponding consumption of energy sources. (Volkswagen, 2012a)

Since the real figures of energy consumption cannot be represented due to confidentiality reasons, the figures were adjusted according to a secret factor which is only known to the author of this dissertation. Hence, the following table provides the adjusted values of the base year and the targeted values in 2018:

Table 60: Adjusted energy and CO_2-emissions of the research and development business unit

Resource and emission flows	Base year (2010)	Target year (2018)
Energy consumption		
Electrical Energy (in MWh/a)	1,033,812	
Technical heat (in MWh/a)	1,029,390	
Fuel gas (in MWh/a)	14,446	
Sum	**2,077,648**	**1,558,236**

Resource and emission flows	Base year (2010)	Target year (2018)
Air emissions (in CO_2-eq.)		
Electrical energy (in t/a)	820,303	
Technical heat (in t/a)	402,323	
Fuel gas (in t/a)	3,020	
Sum	**1,225,646**	**919,235**

Source: According to Volkswagen, 2012a [data adjusted according to secret factor]

For the purpose of this case study, these quantitative environmental goals are transferred to eco-points in order to provide the compatibility of the environmental management control system with the integrated investing method for single investments.

When transferring the values of Table 60 to the eco-factor indicator, it is important to exclude the air emissions since they are already included within the eco-factors for energy consumption. Hence, the environmental goals as expressed within eco-factors are represented in the following table:

Table 61: Environmental goals expressed in eco-points

Consumption	Base year (2010)	Target year (2018)
Energy consumption		
Electrical Energy (in EP/a)	16,627	
Technical heat (in EP/a)	7,705	
Fuel gas (in EP/a)	108	
Sum	**24,440**	**18,330**

Source: Based on Volkswagen, 2012a [data adjusted according to secret factor]

As a consequence, it is necessary to break down the goal of reduction of environmental impacts by 25 percent till 2018 to an annual basis. This is possible by building environmental budgets of eco-points which have to be reduced during a year. These annual budgets can be calculated applying the following formula:

Equation 12: Formula for calculating annual reduction budgets

$$annual\ reduction\ budget\ (in\ eco-points) = \frac{\sum eco{-}points_{base\ year} - \sum eco{-}points_{target\ year}}{target\ year - base\ year}$$

Hence, the annual reduction budget for the business unit of this case study comprises 763.76 eco-points and is calculated as follows:

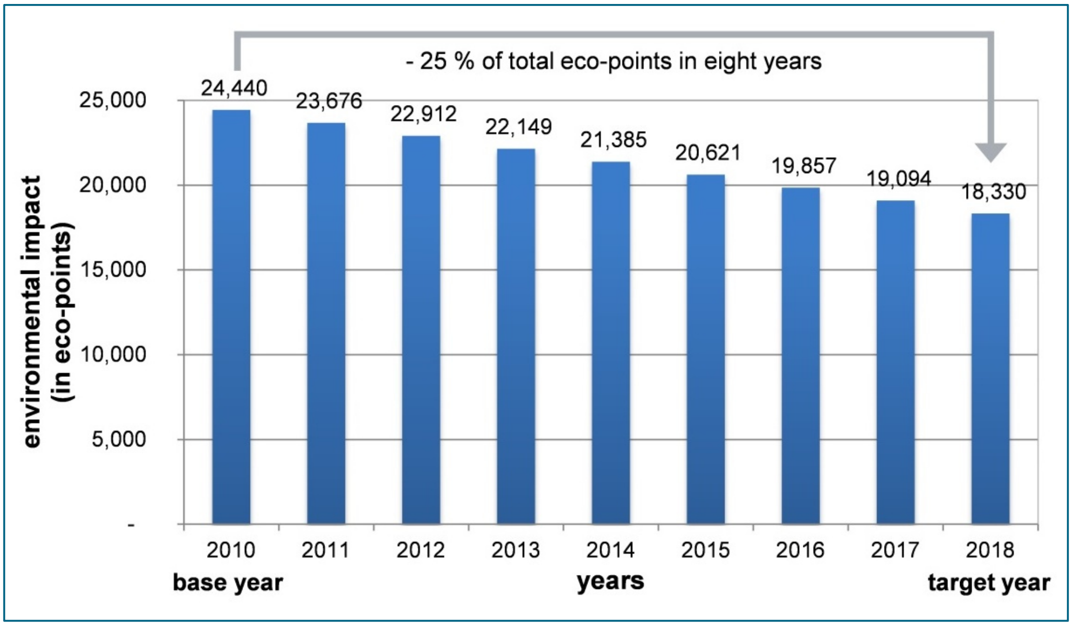
Equation 13: Calculation of annual reduction budgets for this case study

$$763.76\ eco-points = \frac{24{,}440\ ep - 18{,}330\ ep}{2018 - 2010}$$

As a consequence, a linear reduction of environmental impacts is assumed over the eight years for the goal achievement process. The difference between the base year (2010) and the target year (2018) can be equally allocated on the years from 2011 to 2017, resulting in an annual decrease of

763.76 eco-points, representing an annual decrease of 3.125 percent. The resulting annual figures in turn provide the targeted amounts of eco-points per year which the actual performance is measured against in the following step. The targeted amounts of eco-points per year can be retrieved in the following figure:

Figure 71: Targeted amounts of eco-points per year for the business unit



Source: Own illustration based on Volkswagen, 2012a

Process via realisation of investments

The business unit maintains a database in which all environmentally relevant investments are listed. This database is also available to all other business units and intends to provide a knowledge exchange platform of efficiency measures. Hence, the database provides detailed information regarding the following parameters:

- Name of the measure
- Business unit
- Responsible person
- Contact person
- Capital expenditure
- Saved operating expenditure
- Saved environmental aspects
    - Energy (electrical energy, technical heat, fuel gases)
    - Fresh water
    - Air emissions (CO_2-eq., VOC-emissions)
    - Waste
- Status of implementation
- Miscellaneous information

Based on the amount of saved environmental aspects, the eco-points indicator can be added to the database by multiplying the environmental aspect with the corresponding eco-factors. As a consequence, the reduced environmental impact of each measure and the sum of all measures can be expressed in form of eco-points. Regarding the status of implementation, the database differentiates between six types with corresponding milestones, which are listed in the table below:

Table 62: Status types of measures and their corresponding milestones

Status Type	Milestone
Status 1	Idea or potential identified
Status 2	Measure evaluated
Status 3	Measure decided for implementation
Status 4	Measure implemented
Status 5	Financial effect verified
Status 9	Measure rejected

Source: According to Volkswagen, 2014b

The employees are encouraged to submit measures with the first status, which have to be evaluated (status 2) by the responsible person, who is part of the coordinating team of the database within the business unit. The next step (status 3) comprises the decision whether or not the measure is part of the annual investment program. In case of a negative decision, the measure is characterised as ‘status 9’ and the reasons for rejection are added to the measure’s details in the database. With this procedure, it is ensured that other business units can retrieve the details of the measure since it might be possible that the reasons for rejection are business unit-specific and the measure can be realised in other business units. In case of a positive decision, the measure is realised and ends with ‘status 5’ in which the management accounting department verifies the financial savings of the measure. Each measure comprises the status and the corresponding year when the measure has achieved the status. Hence, it is possible to trace back the historic development of each measure along the years and the status information.

Based on the database, it is possible to provide an annual snapshot of planned investment objects, investment objects which are currently in realisation and investment objects which have been realised during the year. In 2015, the database counted more than 134 measures for the research and development business unit. In addition, the capital expenditure as well as the eco-points can be analysed. However due to confidentiality reasons, these information were adjusted according to the same secret factor as the environmental goals.

The following table provides a snapshot of the measures for the business unit for the current year:

Table 63: Snapshot of current investment measures for the business unit

Status	Amount	Capex (in t €)	Reduced environmental impact (in eco-points)
Status 1	17	1,811.85	12.90
Status 2	16	30,000.75	522.19
Status 3	12	84,653.20	386.86
Status 4	0	0.00	0.00
Status 5	89	45,867.30	3,729.71
Sum	**134**	**162,333.10**	**4,651.66**

Source: According to Jaekel, 2014 [data adjusted according to secret factor]

For the correct interpretation of the table above, it is important to notice that the listed measures include measures from several years. For instance, the 89 measures with ‘status 5’ comprise measures for which the financial savings were verified in 2014 and 2015. In addition, the measures in ‘status 1’ and ‘status 2’ also originate from several years and comprise pending measures which were not yet rejected but which were also not yet included in the investment program of the upcoming year. Nevertheless, these measures indicate a potential of reducing the environmental impact, which is important to be provided in the subsequent steps of the environmental management control system of this case study.

Output in form of environmental performance measurement

This step intends to provide an overview of the environmental performance as a result of the realised investments in the previous step. In addition, the environmental performance is set in the context to the input in form of environmental goals and therefore aims to provide information whether or not the business unit is on track of achieving its environmental goals.

Therefore, the environmental performance of the previous years is provided in order to set the current environmental performance in a context of historic development. These environmental performance data originate from the environmental information system of the business unit and are transferred to the eco-points indicator beforehand. Furthermore, the figures are adjusted according to the same secret factor as all the other real data due to confidentiality reasons.

The following table provides an overview of the adjusted environmental performance from the years 2010 to 2014 of the business unit in form of eco-points:

Table 64: Historic environmental performance of the business unit

Year	Eco-points	Difference to previous year
2010	24,440	
2011	21,546	- 11.84 %
2012	22,629	+ 05.02 %
2013	24,022	+ 06.16 %
2014	21,443	- 10.73 %

Source: According to Kitzmann, 2015 [data adjusted according to secret factor]

While the environmental performance improved in the years 2011 and 2014, the opposite happened in the years 2012 and 2013. Hence, it is important to set this actual environmental performance in relation to the environmental goals of the business unit. The originally projected environmental performance assumes an annual reduction of 763.76 eco-points from year 2010 to 2018. This original projection can be compared to the actual reduction of environmental impact which can be retrieved from the environmental information system. The following table compares originally budgeted environmental impacts and actual environmental impacts in form of eco-points:

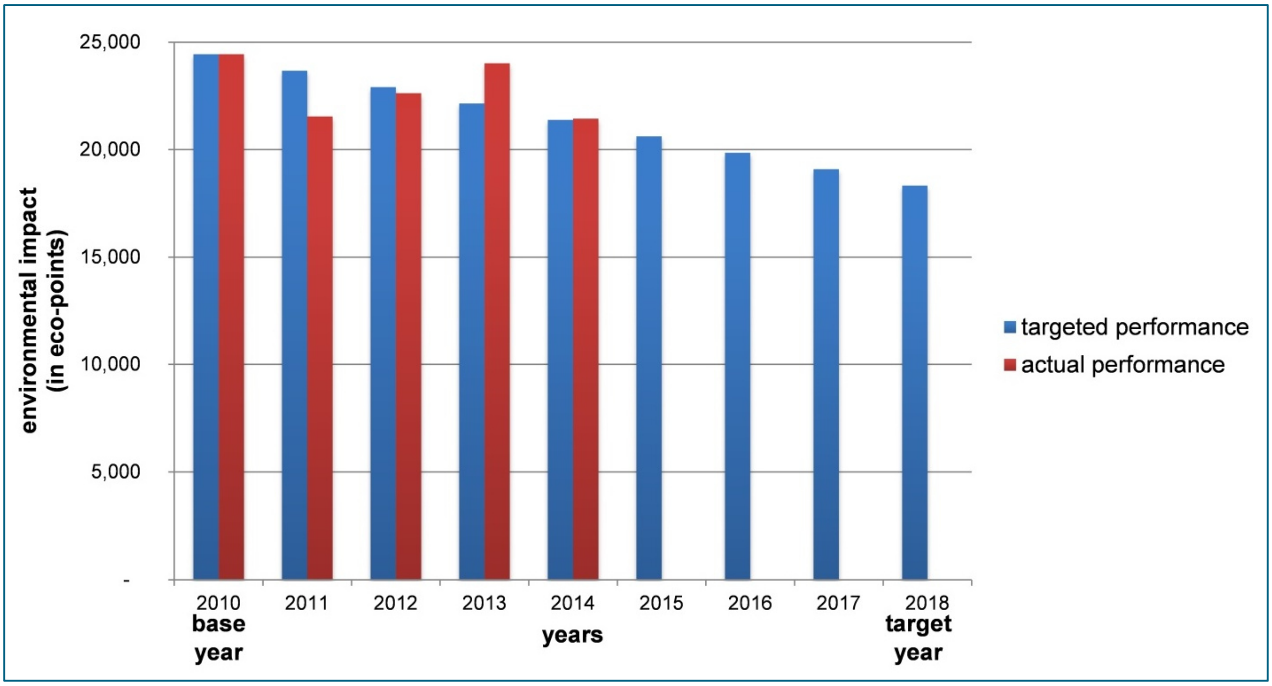
Table 65: Comparison of actual to projected environmental performance of the business unit

Year	Target env. performance (in eco-points)	Actual env. performance (in eco-points)	Difference target to actual environmental performance
2010	24,440	24,440	
2011	23,677	21,546	- 09.00 %
2012	22,913	22,629	- 01.24 %
2013	22,149	24,022	+ 08.46 %
2014	21,385	21,443	+ 00.27 %
2015	20,622		
2016	19,858		
2017	19,094		
2018	18,330		

Source: Own calculations on the basis on Volkswagen, 2012a and Kitzmann, 2015 [data adjusted according to secret factor]

With the help of the table above, the decision-maker is able to assess the actual environmental performance against the targeted performance. Hence, the decision-maker would retrieve the conclusion that the business unit is lacking slightly behind its target, with only 0.27 percent difference. Alternatively, the comparison of targeted and actual environmental performance can be visualised in form of a bar chart as exemplary illustrated in the following figure:

Figure 72: Alternative visualisation of targeted and actual environmental performance of the business unit



Source: Own illustration based on Volkswagen, 2012a and Kitzmann, 2015

An alternative way of reporting comprises the annual reduction budgets instead the total environmental impact data. When reporting this alternative, the difference between the reduction budget and actual reduced eco-points is added (or deducted) to the reduction budget of the following year in analogy to the rolling budgeting process of management accounting (compare Zimmerman, 2011). The following table provides an overview of this alternative way of reporting environmental performance:

Table 66: Comparison of reduction budgets and actual reduction of the business unit

Year	Reduction budget (in eco-points)	Actual reduction (in eco-points)	Difference (in eco-points)
2011	763.76	2,894	-2,130.34
2012	-1,366.58	-1,083	-284.00
2013	479.76	-1,393	1,873.11
2014	2,636.87	2,579	58.18

Source: Own calculations on the basis of Kitzmann, 2015 [data adjusted according to secret factor]

The reporting along the reduction budgets reveals the total differences which are carried forward to the following year. For instance, the actual reduction in 2011 was way higher than the reduction budget, resulting in a negative budget for the following year (i.e. no need for reducing environmental impacts in 2012). In contrast to that, the environmental impact increased in 2013 which resulted in an increase of the budgeted reduction for 2014.

Feedback and corrective actions

The final step of the environmental management control system of this case study is represented by the feedback and corrective actions. Based on the report of the environmental performance within the previous step, the decision-maker knows that the business unit is slightly behind its environmental targets. As consequence of the rolling budgeting process, 58.18 eco-points are added to the annual reduction budget resulting in a total budget of 821.94 eco-points which need to be reduced in 2015.

After the first quarter of 2015, it is possible to provide a forecast of the development of measures and the corresponding impacts on the environmental performance of the business unit. The current situation regarding the amount of measures, their status of implementation as well as the reduced eco-points is depicted in the following table:

Table 67: Overview of the current situation of measures (1st quarter 2015)

Status	Amount	Reduced environmental impact (in eco-points)
Status 1	-	-
Status 2	2	5.94
Status 3	3	47.13
Status 4	-	-
Status 5	49	1,342.28
Sum	**54**	**1,395.36**

Source: Own calculations on the basis of Volkswagen, 2015d [data adjusted according to secret factor]

It is noticeable that there were already a lot of measures realised and the financial effects were verified (i.e. ‘status 5’) within the first quarter of the year. However, their realisation has started already in the previous year but their environmental impact is not deducted from the total environmental impact of the business unit until ‘status 5’ is verified. Given the reduction budget of 821.94 eco-points, the 1,342.28 eco-points which have recently achieved ‘status 5’ already forecast an over-achievement of the annual environmental goal for the year 2015 (see Table 68).

Table 68: Forecast of the current annual environmental impact reduction

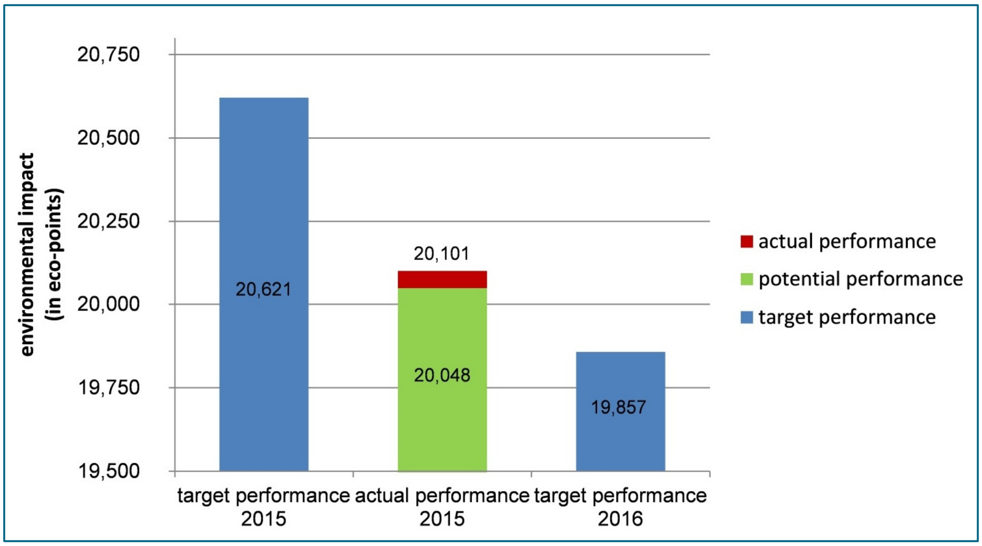
Year	Annual reduction budget (in eco-points)	New ‘status 5’- measures in 2015 (in eco-points)	Difference
2015	821.94	1,342.28	- 520.34

Source: Own calculations on the basis of Volkswagen, 2015d [data adjusted according to secret factor]

In addition, there are measures with ‘status 2’ and ‘status 3’ with a potential for additional 53.08 eco-points that can be deducted from the total environmental impact of the business unit till the end of the current year. In this case, there is potential for the total difference of 573.42 eco-points, assuming that the management accounting department also verifies this potential. As a consequence, the annual reduction budget for 2016 would be 190.29 eco-points (763.71 eco-points annual reduction budget – 573.42 eco-points difference).

The amount of reduced eco-points can be deducted from the actual environmental performance of the previous year in order to derive a forecast of the actual environmental performance of the current year 2015. Furthermore, potentials can be visualised by additionally deducting the sum of the saved eco-points of all measures with ‘status 1’ to ‘status 4’. To provide additional orientation for the decision-maker, these two amounts are set in relation to the target value of the upcoming year. The forecast of actual, potential and targeted amounts of this business unit can be retrieved in the following figure:

Figure 73: Forecast of actual, potential and targeted environmental performance of the business unit



Source: Own illustration based on Volkswagen, 2012a and Volkswagen, 2105d [data adjusted according to secret factor]

Although the annual environmental goal for 2015 is going to be achieved, the database provides the additional insight that there are only two more measures left in the pipeline of potential future measures. Hence, the corrective action in this step might involve encouraging employees and management to search for additional measures so that measures of ‘status 1’ and ‘status 2’ are generated. This encouragement would ensure that there are sufficient measures over which their implementation can be decided in 2016 in order to reach the environmental goal of the subsequent year. Furthermore, a target value for these measures can be set at a minimum of 190.29 eco-points since this is going to be the reduction budget for 2016 in case all remaining ‘status 3’-measures are realised and transferred to ‘status 5’ in 2015.

5.3.6. Management and control of environmental goals for a production site

This case study intends to provide answers to the research question of how to manage and control the achievement of strategic environmental goals of a company. Therefore, the case study is structured along the process of an environmental management control system.

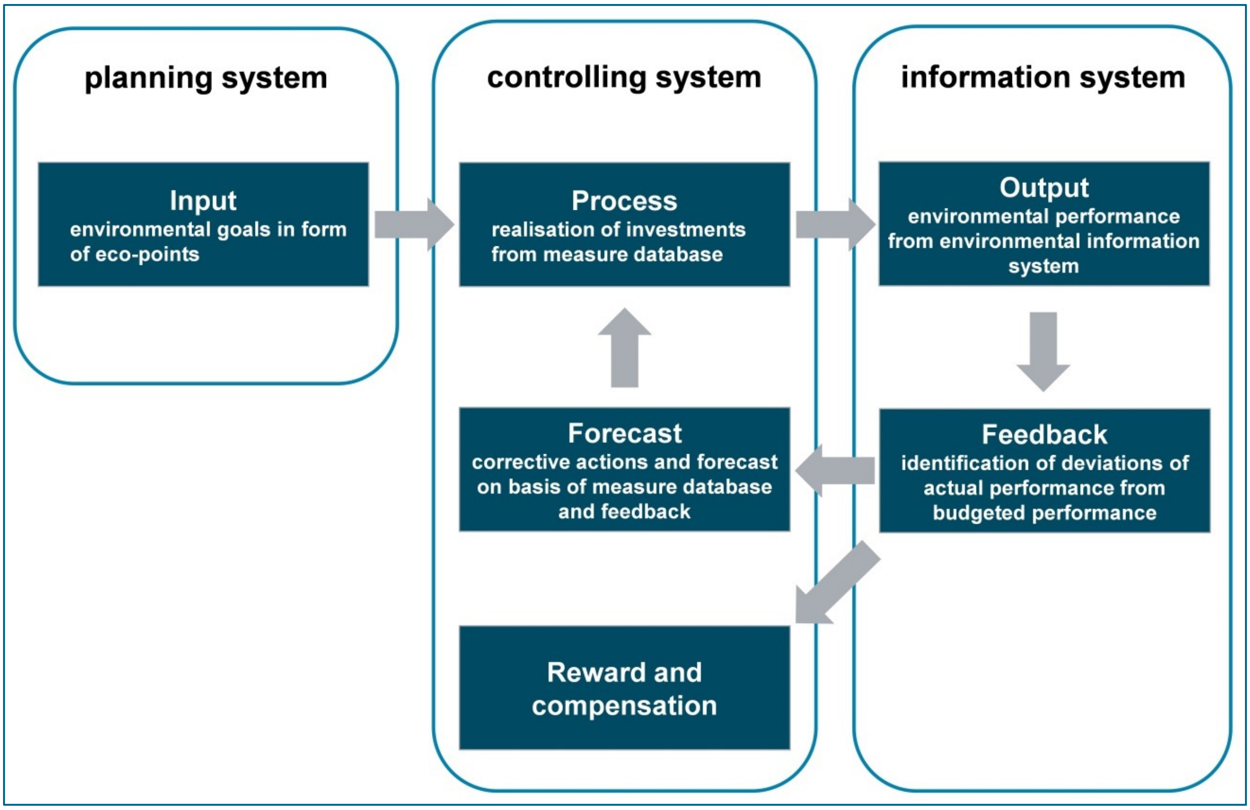
Context of the case

The context of this case study is represented by the production site of the Volkswagen Group situated in Germany. With more than 60,000 employees, this production site is one of the biggest within the group. The production site comprises the press shop, body shop, paint shop and final assembly of three car models. In addition, there are several components of various car models produced at the site, which are also exported to other production sites of the Volkswagen Group.

Description of the case along the environmental management control system

The environmental management control system in context of this case study draws on the MCS as described within the definition of the unit of analysis. Hence, it assumes a process, represented by the realisation of investments within the time period under consideration. The input to this process is represented by environmental goals that can be expressed in a targeted amount of reduced eco-points within the same time period. The output of this process in form of the environmental performance is compared to the expected or targeted environmental performance. On the basis of this comparison, the decision-maker has to induce corrective actions, if necessary, which impacts are forecasted as inputs on the process. In addition, it is assumed that there is a compensation system in place rewarding the decision-maker for achieving the given environmental goals. The following figure illustrates the management control system within this case study:

Figure 74: Environmental management control system in the context of this case study



Source: According to Schäffer, 2013; Zhang, 2014; Strauß and Zecher, 2013

Input in form of environmental goals

The environmental goals of the production site are set in line with the strategic environmental goals of the Volkswagen Group. Therefore, they comprise a relative reduction of five KPIs (energy, fresh water, waste, air emissions in form of VOC and CO_2-equivalents) by 25 percent till 2018, based on the values of 2010. While energy comprises electrical energy, technical heat and the consumption of fuel gas, the CO_2-air emissions are summarised in CO_2-equivalents and are calculated via emission factors, based on the corresponding consumption of energy sources. (Volkswagen, 2012b)

These reduction goals are relative goals. As a consequence, the reduction of 25 percent is measured per manufactured car or per manufactured component product. Nevertheless, the consumption of energy, for instance, does not completely depend on the amount of manufactured cars, which means that the production site consumes energy even in non-production times. This part of energy consumption is referred as ‘base load’ or ‘minimum load’ (Bhattacharyya, 2011). Hence, with increasing amounts of manufactured cars, the amount of base load per manufactured car decreases, which concludes an increased efficiency. However, the way of manufactured cars might have kept the same which would conclude only a calculated efficiency improvement due to the ‘volume effect’. Since the impact of this ‘volume effect’ on the environmental goals is not sufficiently analysed so far, this case study assumes a 25 percent reduction goal on the above-mentioned environmental aspects in absolute values.

Since the real figures of the five KPIs cannot be represented due to confidentiality reasons, the figures were adjusted according to a secret factor which is only known to the author of this dissertation. Hence, the following table provides the adjusted values of the base year and the targeted values in 2018:

Table 69: Adjusted value of the environmental goals in form of five KPIs for the production site

Resource and emission flows	Base year (2010)	Target year (2018)
Fresh water consumption (in m^3/a)	14,100,961	10,575,721
Waste production (in t/a)	48,345	36,259
Energy consumption (in MWh/a)	14,475,757	10,856,818
Air emissions in CO_2-equivalents (in t/a)	7,629,702	5,722,277
Air emissions in form of VOCs (in t/a)	9,387	7,040

Source: According to Volkswagen, 2012b [data adjusted according to secret factor]

For the purpose of this case study, these quantitative environmental goals are transferred to eco-points in order to provide the compatibility of the environmental management control system with the integrated investing method for single investments. Hence, the environmental goals as expressed within eco-points are represented in the following table:

Table 70: Environmental goals expressed in eco-points

	Base year (2010)	Target year (2018)
Fresh water consumption (in eco-points/a)	319	239
Waste production (in eco-points/a)	353	265
Energy consumption (in eco-points/a)	232,819	174,614
Air emissions in form of VOCs (in eco-points/a)	13,846	10,384
Sum	**247,337**	**185,502**

Source: According to Volkswagen, 2012b [data adjusted according to secret factor]

As a consequence, it is necessary to break down the goal of reduction of environmental impacts by 25 percent till 2018 to an annual basis. This is possible by building environmental budgets of eco-points which have to be reduced during a year. These annual budgets can be calculated applying the following formula:

Equation 14: Formula for calculating annual reduction budgets

$$annual\ reduction\ budget\ (in\ eco-points) = \frac{\sum eco{-}points_{base\ year} - \sum eco{-}points_{target\ year}}{target\ year - base\ year}$$

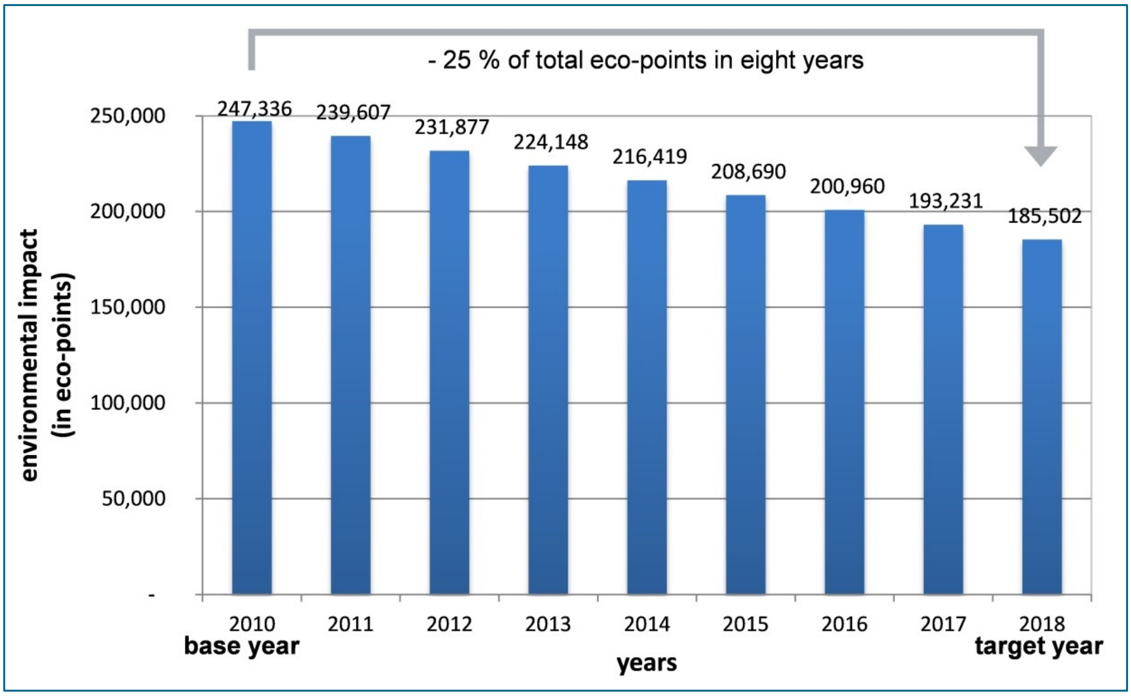
Hence, the annual reduction budget for this case study comprises 7,729.37 eco-points and is calculated as follows:

Equation 15: Calculation of annual reduction budgets for this case study

$$7{,}729.37\ eco-points = \frac{247{,}337\ ep - 185{,}502\ ep}{2018 - 2010}$$

As a consequence, a linear reduction of environmental impacts is assumed over the eight years of the goal achievement process. The difference between the base year (2010) and the target year (2018) can be equally allocated on the years from 2011 to 2017, resulting in an annual decrease of 7,729.37 eco-points representing an annual decrease of 3.125 percent. The resulting annual figures in turn provide the targeted amounts of eco-points per year, which the actual performance is measured against in the following step. The targeted amounts of eco-points per year can be retrieved in the following figure:

Figure 75: Targeted amounts of eco-points per year for the production site



Source: Own illustration based on Volkswagen, 2012b [data adjusted according to secret factor]

Process via realisation of investments

The production site maintains a database in which all environmentally relevant investments are listed. This database is also available to all other production sites and intends to provide a knowledge exchange platform of efficiency measures within the Volkswagen Group. Hence, the database provides detailed information regarding the following parameters:

- Name of the measure
- Production site
- Business unit
- Responsible person
- Capital expenditure
- Saved operating expenditure
- Saved environmental aspects
    - Energy (electrical energy, technical heat, fuel gases)
    - Fresh water
    - Air emissions (CO_2-eq., VOC-emissions)
    - Waste
- Status of implementation
- Miscellaneous information

Based on the amount of saved environmental aspects, the eco-points indicator can be added to the database by multiplying the environmental aspect with the corresponding eco-factor. As a consequence, the reduced environmental impact of each measure and the sum of all measures can be expressed in form of eco-points.

Regarding the status of implementation, the database differentiates between six types with corresponding milestones, which are listed in the table below:

Table 71: Status types of measures and their corresponding milestones

Status Type	Milestone
Status 1	Idea or potential identified
Status 2	Measure evaluated
Status 3	Measure decided for implementation
Status 4	Measure implemented
Status 5	Financial effect verified
Status 9	Measure rejected

Source: According to Volkswagen, 2014b

The employees are encouraged to submit measures with the first status, which have to be evaluated (status 2) by the responsible person, who is part of the coordinating team of the database within the production site. The next step (status 3) comprises the decision whether or not the measure is part of the annual investment program. In case of a negative decision, the measure is characterised as ‘status 9’ and the reasons for rejection are added to the measure’s details in the database.

With this procedure, it is ensured that other production sites can retrieve the details of the measure since it might be possible that the reasons for rejection are production site-specific and the measure can be realised in other production sites. In case of a positive decision, the measure is realised and ends with ‘status 5’ in which the management accounting department verifies the financial savings of the measure. Each measure comprises the status and the corresponding year when the measure has achieved the status. Hence, it is possible to trace back the historic development of each measure along the years and the status information.

Based on the database, it is also possible to provide an annual snapshot of planned investment objects, investment objects which are currently in realisation and investment objects which have been realised during the year. In 2015, the database counted more than 223 measures for the whole production site. In addition, the capital expenditure as well as the eco-points can be analysed. However, these information were adjusted according the same secret factor as the environmental goals due to confidentiality reasons.

The following table provides a snapshot of the measures for the production site of this context for the current year:

Table 72: Snapshot of current investment measures

Status type	Amount	Capex (in t €)	Reduced environmental impact (in eco-points)
Status 1	1	20.92	07.99
Status 2	10	18,420.43	1,560.82
Status 3	28	85,349.21	6,189.73
Status 4	14	25,026.90	3,247.75
Status 5	31	26,872.91	1,182.13
Status 9	139	2.641,480.61	82,966.68
Sum	**223**	**2,797,170.98**	**95,155.10**

Source: According to Volkswagen, 2015d [data adjusted according to secret factor]

For the correct interpretation of the table above, it is important to notice that the listed measures include measures from several years. While the 31 measures with 'status 5' comprise measures for which the financial savings were verified in 2015, the measures in the remaining status types originate from several years and comprise measures which were not yet rejected but which were also not yet included in the investment program of the upcoming year. Nevertheless, these measures indicate a potential of reducing the environmental impact which is important to be provided in the subsequent steps of the environmental management control system of this case study.

Output in form of environmental performance measurement

This step intends to provide an overview of the environmental performance as a result of the realised investments in the previous step. In addition, the environmental performance is set in context to the input in form of environmental goals and thus aims to provide the answer whether or not the production site is on track of achieving the environmental goals.

Therefore, the environmental performance of the previous years is provided in order to set the current environmental performance in a context of historic development. These environmental performance data originate from the environmental information system of the production site and are transferred to the eco-points indicator beforehand.

Furthermore, the figures are adjusted according to the same secret factor as all the other real data due to confidentiality reasons. The following table provides an overview of the adjusted environmental performance from the years 2010 to 2014 of the production site in form of eco-points:

Table 73: Historic environmental performance of the production site

Year	Eco-points	Difference to previous year
2010	247,337	
2011	228,181	- 7.74 %
2012	231,392	+ 1.41 %
2013	235,778	+ 1.90 %
2014	218,701	- 7.24 %

Source: According to Kitzmann, 2015 [data adjusted according to secret factor]

While the environmental performance improved in the years 2011 and 2014, the opposite happened in the years 2012 and 2013. Hence, it is important to set this actual environmental performance in relation to the environmental goals of the production site. The originally projected environmental performance assumes an annual reduction of 7,729.37 eco-points from the year 2010 to 2018. This original projection can be compared to the actual reduction of environmental impact which can be retrieved from the environmental information system.

The following table compares originally budgeted environmental impacts and actual environmental impacts in form of eco-points:

Table 74: Comparison of actual to projected environmental performance of the production site

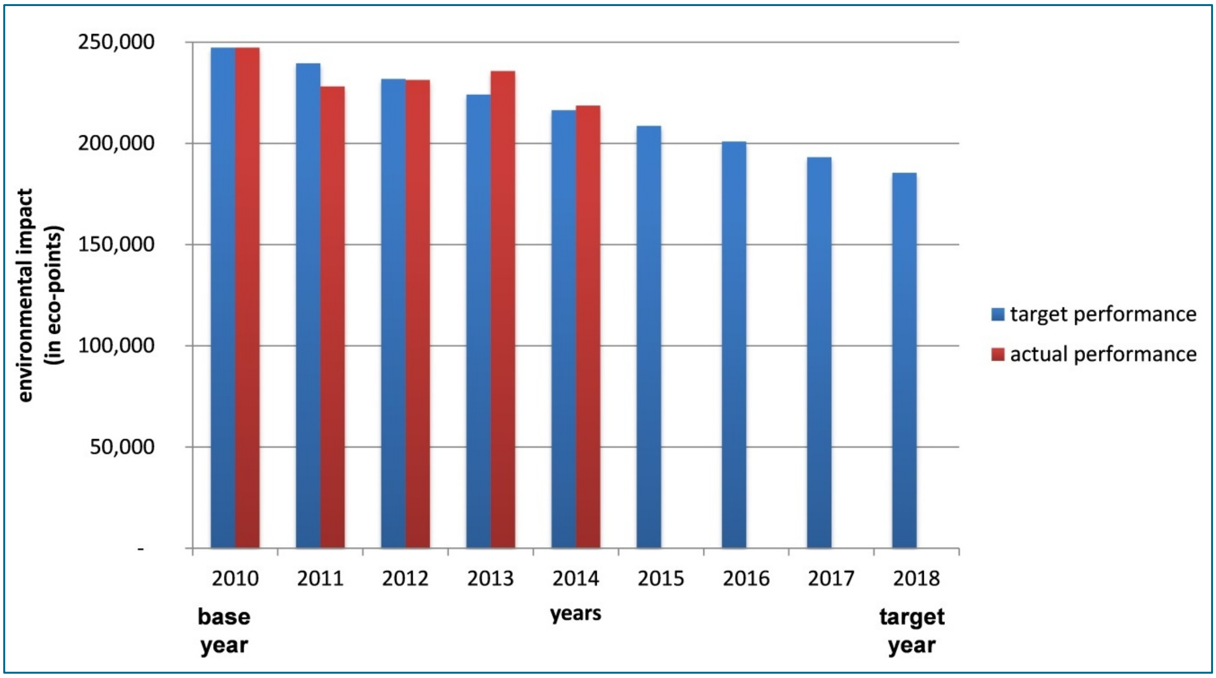
Year	Target env. performance (in eco-points)	Actual env. performance (in eco-points)	Difference target to actual environmental performance
2010	247,337	247,337	
2011	239,607	228,181	- 4.77 %
2012	231,878	231,392	- 0.21 %
2013	224,149	235,778	+ 5.19 %
2014	216,419	218,701	+ 1.05 %
2015	208,690		
2016	200,961		
2017	193,232		
2018	185,502		

Source: Own calculations on the basis of Kitzmann, 2015 [data adjusted according to secret factor]

With the help of the table above, the decision-maker can assess the actual environmental performance against the targeted performance and thus would retrieve the conclusion that the production site is lacking slightly behind its target with only 1.05 percent difference.

Alternatively, the decision-maker can visualise the targeted and the actual environmental performance in form of bar chart comparison as exemplarily illustrated in the following figure:

Figure 76: Alternative visualisation of targeted and actual environmental performance of the production site



Source: Own illustration based on Volkswagen, 2012b and Kitzmann, 2015 [data adjusted according to secret factor]

An alternative way of reporting can comprise the annual reduction budgets instead the total environmental impact data. When reporting this alternative, the difference between the reduction budget and actual reduced eco-points is added or deducted to the reduction budget of the following year in analogy to the rolling budgeting process of management accounting (compare Zimmerman, 2011). The following table provides an overview of this alternative way of reporting environmental performance:

Table 75: Comparison of reduction budgets and actual reduction of the production site

Year	Reduction budget (in eco-points)	Actual reduction (in eco-points)	Difference (in eco-points)
2011	7,729.27	19,155	- 11,425.87
2012	- 3,696.61	- 3,211	- 485.96
2013	7,243.31	- 4,386	11,629.51
2014	19,358.78	17,077	2,281.94

Source: Own calculations on the basis of Kitzmann, 2015 [data adjusted according to secret factor]

The reporting along the reduction budgets reveals the total differences which are carried forward to the following year. For instance, the actual reduction in 2011 was way higher than the reduction budget, resulting in a negative budget for the following year (i.e. no need for reducing environmental impacts in 2012). In contrast to that, the environmental impact increased in 2013 which resulted in an increase of budgeted reduction for 2014.

Feedback and corrective actions

The final step of the environmental management control system of this case study is represented by the feedback and corrective actions. Based on the report of the environmental performance within the previous step, the decision-maker knows that the production site is slightly behind its environmental targets. As a consequence of the rolling budgeting process, 2,281.94 eco-points are added to the annual reduction budget resulting in a total budget of 10,011.21 eco-points which need to be reduced in 2015.

After the first quarter of 2015, it is possible to provide a forecast of the development of measures and the corresponding impacts on the environmental performance of the production site. The current situation regarding the amount of measures, their status of implementation as well as the reduced eco-points is depicted in the following table:

Table 76: Overview of the current situation of measures for the production site (1st quarter 2015)

Status	Amount	Reduced env. impact (in eco-points)
Status 1	1	7.99
Status 2	10	1,560.82
Status 3	28	6,189.73
Status 4	14	3,247.75
Status 5	31	1,182.13
Sum	**84**	**12,188.42**

Source: Own calculations on the basis of Volkswagen, 2015d [data adjusted according to secret factor]

It is noticeable that there were already a lot of measures realised and the financial effects were verified (i.e. ‘status 5’) within the first quarter of the year. However, their realisation has started already in the previous year but their environmental impact is not deducted from the total environmental impact of the production site unless the ‘status 5’ is achieved. Given the reduction budget of 10,011.21 eco-points, the 1,182.13 eco-points which have recently achieved ‘status 5’ already forecast an under-achievement of the annual environmental goal (see Table 68).

Table 77: Forecast of the current annual environmental impact reduction

Year	Annual reduction budget (in eco-points)	New ‘status 5’- measures in 2015 (in eco-points)	Difference
2015	10,011.21	1,182.13	8,829.07

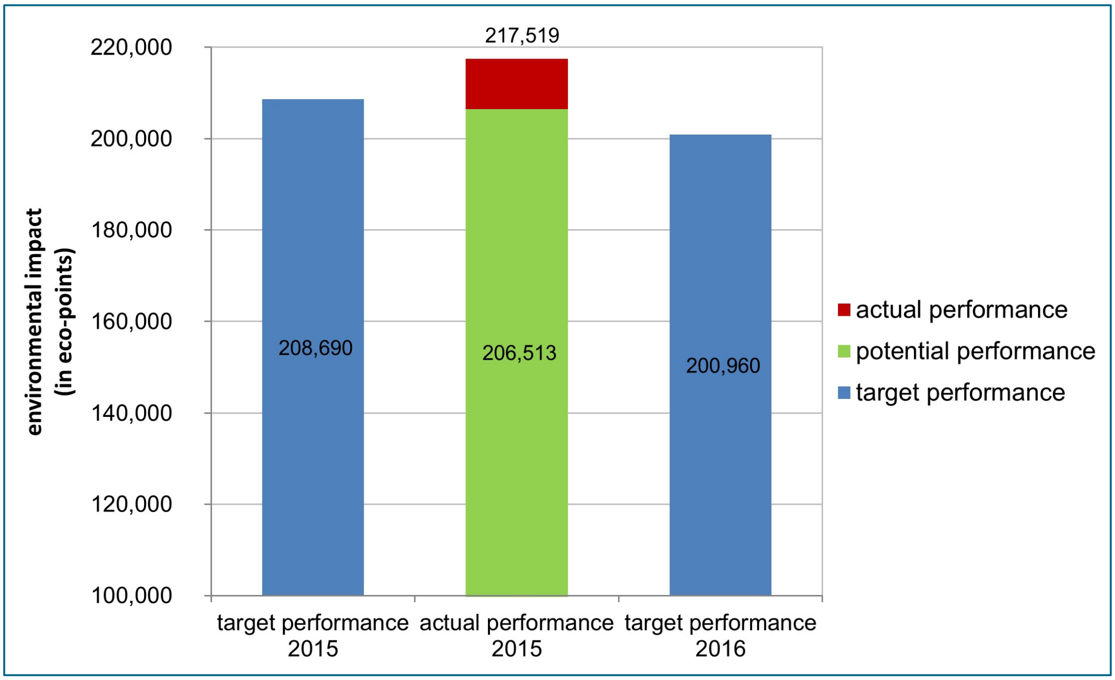
Source: Own calculations on the basis of Volkswagen, 2015d [data adjusted according to secret factor]

There are additional measures with ‘status 2’, ‘status 3’ and ‘status 4’ in the pipeline representing a potential for additional 11,006.30 eco-points that can be deducted from the total environmental impact of the production site till the end of the current year. In this case, there is potential for the total difference of -2,177.23 eco-points, assuming that the management accounting department verifies this potential. As a consequence, the annual reduction budget for 2016 would be 5,552.04 eco-points (7,729.27 eco-points annual reduction budget – 2,177.23 eco-points difference).

With this forecast, the decision-maker knows that the production site is not going to meet the annual environmental reduction goal, even if all measures in the pipeline were transferred to 'status 5'. Therefore, the corrective action would be to encourage transferring the measures to 'status 5' as soon as possible. Besides the amount of reduced eco-points, the database also reveals the capital expenditure necessary to realise the investment measures. In this case, the sum of all measures in 'status 1' and 'status 2' is about 18,441,348 Euro (value was adjusted). Regarding the measures with 'status 3' and 'status 4', the investment decision has already taken place, so the decision-maker has to focus on transferring these measures to 'status 5' as soon as possible.

The amount of actually reduced eco-points can be deducted from the actual environmental performance of the previous year in order to derive a forecast of the actual environmental performance of the year 2015. Furthermore, potentials can be visualised by additionally deducting the saved eco-points of all measures with 'status 1' to 'status 4'. To provide additional orientation for the decision-maker, these two amounts are set in relation to the target value of the upcoming year. The forecast of actual, potential and targeted amounts of this production site can be retrieved in the following figure:

Figure 77: Forecast of actual, potential and targeted environmental performance of the production site



Source: Own illustration based on Volkswagen, 2012b and Volkswagen, 2105d [data adjusted according to secret factor]

Additional corrective action in this step might comprise encouraging employees and management to search for additional measures so that new measures can be generated. This encouragement would ensure that there are sufficient measures over which implementation can be decided in 2016 in order to reach the environmental goal of the subsequent year. Furthermore, a target value for these measures can be set at a minimum of 5,552.04 eco-points since this is going to be the reduction budget for 2016 in case all remaining measures are realised and transferred to ‘status 5’ in 2015.

5.3.7. Management and control of environmental goals for five production sites

This case study intends to provide answers to the research question of how to manage and control the achievement of strategic environmental goals of a company. Therefore, the case study is structured along the process of an environmental management control system.

Context of the case

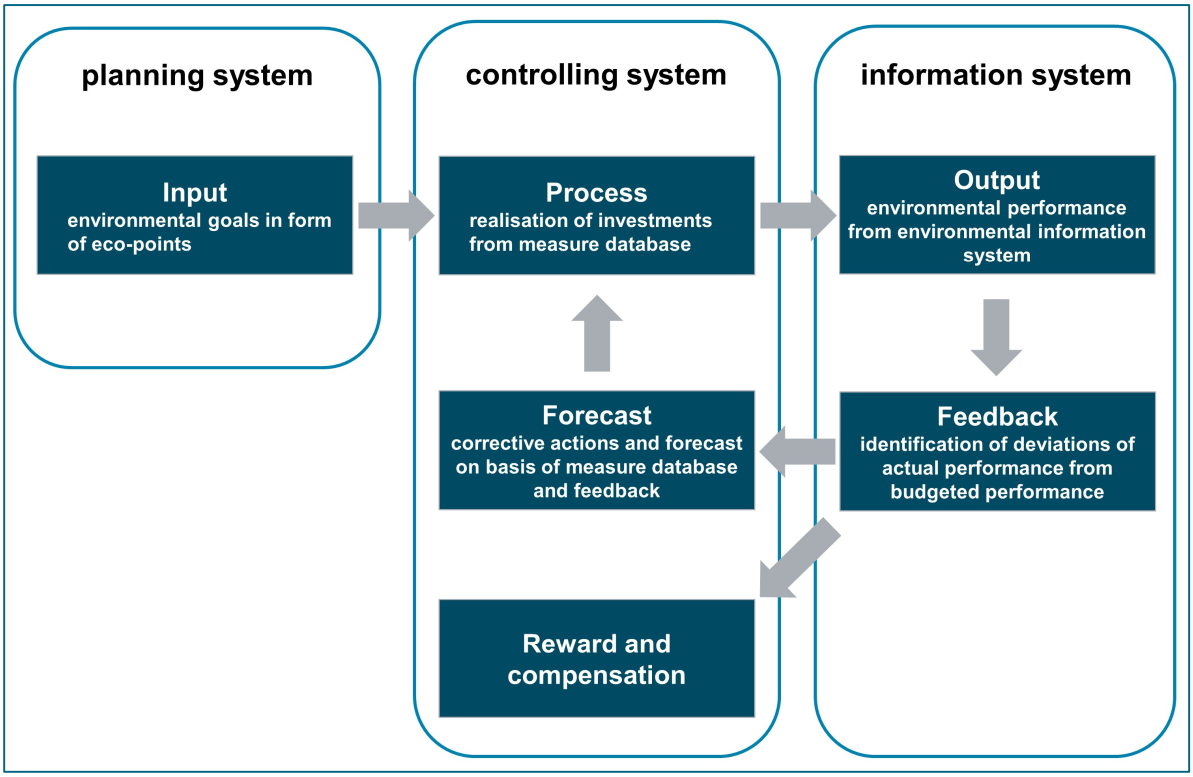
The context of this case study is represented by five production sites of the Volkswagen Group situated in Germany. These production sites comprise car manufacturing sites but also components production sites. In the context of this case study, the names of the sites and their locations are anonymised. Therefore, the sites are numbered from one to five.

Description of the case along the environmental management control system

The environmental management control system in context of this case study draws on the MCS as described within the definition of the unit of analysis. Hence, it assumes a process, represented by the realisation of investments within the time period under consideration. The input to this process is represented by environmental goals that can be expressed in a targeted amount of reduced eco-points within the same time period. The output of this process in form of the environmental performance is compared to the expected or targeted environmental performance. On the basis of this comparison, the decision-maker has to induce corrective actions, if necessary, which impacts are forecasted as inputs on the process. In addition, it is assumed that there is a compensation system in place rewarding the decision-maker for achieving the given environmental goals.

The following figure illustrates the management control system within this case study:

Figure 78: Environmental management control system in the context of this case study



Source: According to Schäffer, 2013; Zhang, 2014; Strauß and Zecher, 2013

Input in form of environmental goals

The environmental goals of the five production sites are set in line with the strategic environmental goals of the Volkswagen Group. Thus they comprise a relative reduction of five KPIs (energy, fresh water, waste, air emissions in form of VOC and CO_2-equivalents) by 25 percent till 2018, based on the values of 2010. While energy comprises electrical energy, technical heat and the consumption of fuel gas, the CO_2-air emissions are summarised in CO_2-equivalents and calculated via emission factors, based on the corresponding consumption of energy sources. (Volkswagen, 2012c)

These reduction goals are relative goals. As a consequence, the reduction of 25 percent is measured per manufactured car or per manufactured component product. However, the consumption of energy, for instance, does not completely depend on the amount of manufactured cars, which means that the production site consumes energy even in non-production times. This part of energy consumption is referred as ‘base load’ or ‘minimum load’ (Bhattacharyya, 2011).

Hence, with increasing amounts of manufactured cars, the amount of base load per manufactured car gets smaller which concludes an increased efficiency. Nevertheless, the way of manufacturing cars might have kept the same, which would conclude only a calculated efficiency improvement due to the ‘volume effect’. Since the impact of this ‘volume effect’ on the environmental goals is not sufficiently analysed so far, this case study assumes a 25 percent reduction goal on the above-mentioned environmental aspects in absolute values.

For the purpose of this case study, the environmental goals, which are quantified in form of resource and emission flows, are transferred to eco-points in order to provide the compatibility of the environmental management control system with the integrated investing method for single investments. When transferring the resource and emission flows to the eco-point indicator, it is important to exclude the air emissions in CO_2-equivalents since they are already included within the eco-factors for energy consumption. Hence, the environmental goals as expressed in form of eco-points are represented in the following table:

Table 78: Environmental goals expressed in eco-points for the five production sites

	Base year (2010)	Target year (2018)
Sum of eco-points site 1	54,370.52	40,777.89
Sum of eco-points site 2	63,708.08	47,781.06
Sum of eco-points site 3	140,532.68	105,399.51
Sum of eco-points site 4	49,919.87	37,439.90
Sum of eco-points site 5	247,336.51	185,502.38
Sum	**555,867.65**	**416,900.74**

Source: According to Volkswagen, 2012c [data adjusted according to secret factor]

As a consequence, it is necessary to break down the goal of reduction of environmental impacts by 25 percent till 2018 to an annual basis. This is possible by building environmental budgets of eco-points which have to be reduced during a year. These annual budgets can be calculated applying the following formula:

Equation 16: Formula for calculating annual reduction budgets

$$annual\ reduction\ budget\ (in\ eco-points) = \frac{\sum eco\text{-}points_{base\ year} - \sum eco\text{-}points_{target\ year}}{target\ year - base\ year}$$

Hence, the annual reduction budget for this case study comprises 17,370.86 eco-points and is calculated as follows:

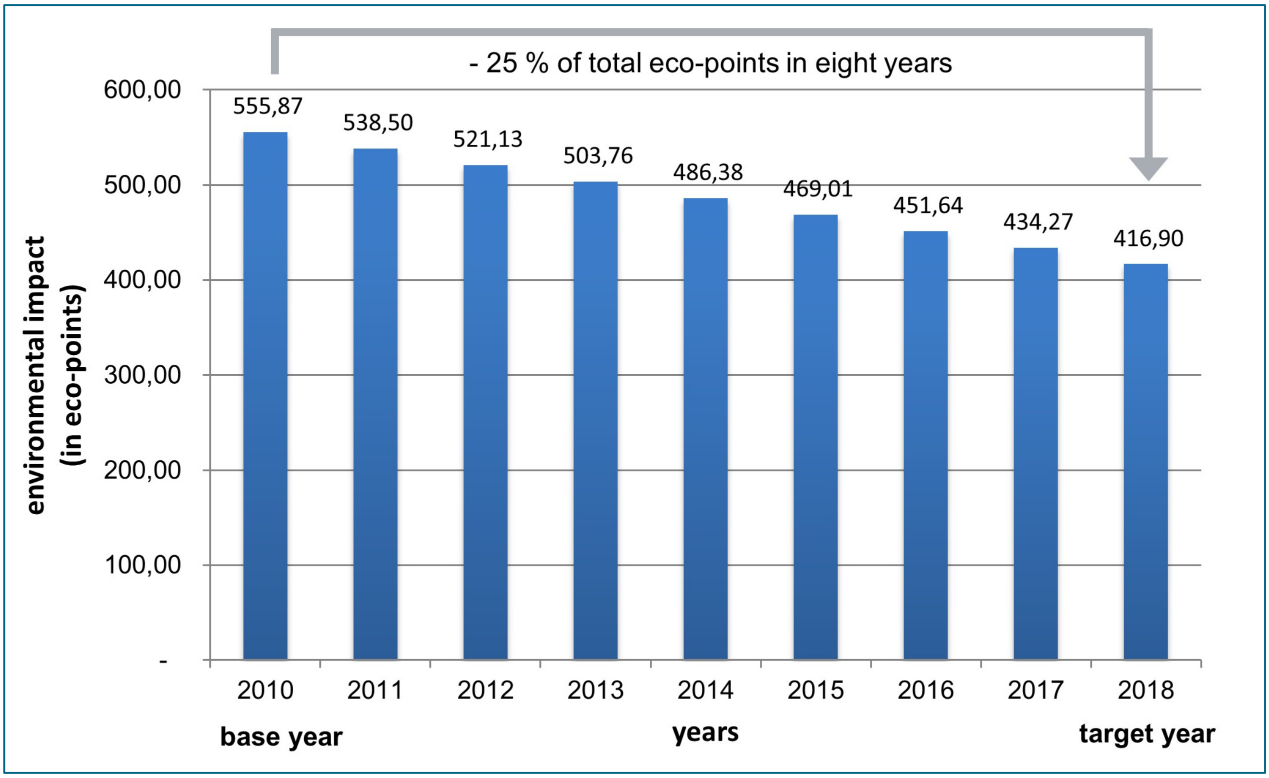
Equation 17: Calculation of annual reduction budgets for this case study

$$17{,}370.86\ eco-points = \frac{555{,}867.65\ ep - 416{,}900.74\ ep}{2018 - 2010}$$

As a consequence, a linear reduction of environmental impacts is assumed over the eight years of the goal achievement process. The difference between the base year (2010) and the target year (2018) can be equally allocated on the years from 2011 to 2017, resulting in an annual decrease of 17,370.86 eco-points representing an annual decrease of 3.125 percent. The resulting annual figures in turn provide the targeted amounts of eco-points per year which the actual performance is measured against in the following step.

The targeted amounts of eco-points per year can be retrieved in the following figure:

Figure 79: Targeted amounts of eco-points per year for the five production sites



Source: Own illustration based on Volkswagen, 2012c [data adjusted according to secret factor]

Process via realisation of investments

The production sites maintain a database in which all environmentally relevant investments are listed. Hence, the database provides detailed information regarding the following parameters:

- Name of the measure
- Production site
- Business unit
- Responsible person
- Contact person
- Capital expenditure
- Saved operating expenditure
- Saved environmental aspects
    - Energy (electrical energy, technical heat, fuel gases)
    - Fresh water
    - Air emissions (CO_2-eq., VOC-emissions)
    - Waste
- Status of implementation
- Miscellaneous information

Based on the amount of saved environmental aspects, the eco-points indicator can be added to the database by multiplying the environmental aspect with the corresponding eco-factor. As a consequence, the reduced environmental impact of each measure and the sum of all measures can be expressed in form of eco-points.

Regarding the status of implementation, the database differentiates between six types with corresponding milestones, which are listed in the table below:

Table 79: Status types of measures and their corresponding milestones

Status Type	Milestone
Status 1	Idea or potential identified
Status 2	Measure evaluated
Status 3	Measure decided for implementation
Status 4	Measure implemented
Status 5	Financial effect verified
Status 9	Measure rejected

Source: According to Volkswagen, 2014b

The employees are encouraged to submit measures with the first status, which have to be evaluated (status 2) by the responsible person, who is part of the coordinating team of the database within the production site. The next step (status 3) comprises the decision whether or not the measure is part of the annual investment program. In case of a negative decision, the measure is characterised as 'status 9' and the reasons for rejection are added to the measure's details in the database. With this procedure, it is ensured that other production site can retrieve the details of the measure since it might be possible that the reasons for rejection are production site-specific and the measure can be realised in other production site. In case of a positive decision, the measure is realised and ends with 'status 5' in which the management accounting department verifies the financial savings of the measure. Each measure comprises the status and the corresponding year when the measure has achieved the status. Hence, it is possible to trace back the historic development of each measure along the years and the status information.

Based on the database, it is also possible to provide an annual snapshot of planned investment objects, investment objects which are currently in realisation and investment objects which have been realised during the year. In 2015, the database counted more than 393 measures for the five production sites. In addition, the capital expenditure as well as the eco-points can be analysed. However, these information were adjusted according the same secret factor as the environmental goals due to confidentiality reasons.

The following table provides a snapshot of the measures for the five production sites of this context for the current year:

Table 80: Snapshot of current investment measures of the five production sites

Status	Amount	Capex (in t €)	Reduced environmental impact (in eco-points)
Status 1	7	3,332.18	116.03
Status 2	28	195,968.01	3,609.95
Status 3	60	133,211.07	8,474.22
Status 4	28	84,272.42	4,537.42
Status 5	51	48,983.28	1,841.32
Status 9	219	2,773,252.94	87,868.21
Sum	**393**	**3,239,019.90**	**106,447.15**

Source: According to Volkswagen, 2015d [data adjusted according to secret factor]

For the correct interpretation of the table above, it is important to notice that the listed measures include measures from several years. While the 51 measures with 'status 5' comprise measures for which the financial savings were verified in the year 2015, the measures in 'status 1' and 'status 2' originate from several years and comprise measures which were not yet rejected but which were also not yet included in the investment program of the upcoming year. Nevertheless, these measures indicate a potential of reducing the environmental impact which is important to be provided in the subsequent steps of the environmental management control system of this case study.

Output in form of environmental performance measurement

This step intends to provide an overview of the environmental performance as result of the realised investments in the previous step. In addition, the environmental performance is set in the context to the input in form of environmental goals and therefore aims to provide the answer whether or not the five production sites are on track of achieving their environmental goals.

Therefore, the environmental performance of the previous years is provided in order to set the current environmental performance in a context of historic development. These environmental performance data originate from the environmental information system of the production site and are transferred to the eco-points indicator beforehand. Furthermore, the figures are adjusted according to the same secret factor as all the other real data due to confidentiality reasons.

The following table provides an overview of the adjusted environmental performance from 2010 to 2014 of the production sites in form of eco-points:

Table 81: Sum of the historic environmental performance of the five production sites

Year	Eco-points	Difference to previous year
2010	555,867.65	
2011	526,703.47	- 5.25 %
2012	532,078.99	+ 1.02 %
2013	538,961.70	+ 1.29 %
2014	507,445.44	- 5.85 %

Source: According to Kitzmann, 2015 [data adjusted according to secret factor]

While the environmental performance improved in the years 2011 and 2014, the opposite happened in the years 2012 and 2013. Hence, it is important to set this actual environmental performance in relation to the environmental goals of the production sites. The originally projected environmental performance assumes an annual reduction of 17,370.86 eco-points from the year 2010 to 2018. This original projection can be compared to the actual reduction of environmental impact which can be retrieved from the environmental information system. The following table compares originally budgeted environmental impacts and actual environmental impacts in form of eco-points:

Table 82: Comparison of actual to projected environmental performance of the five production sites

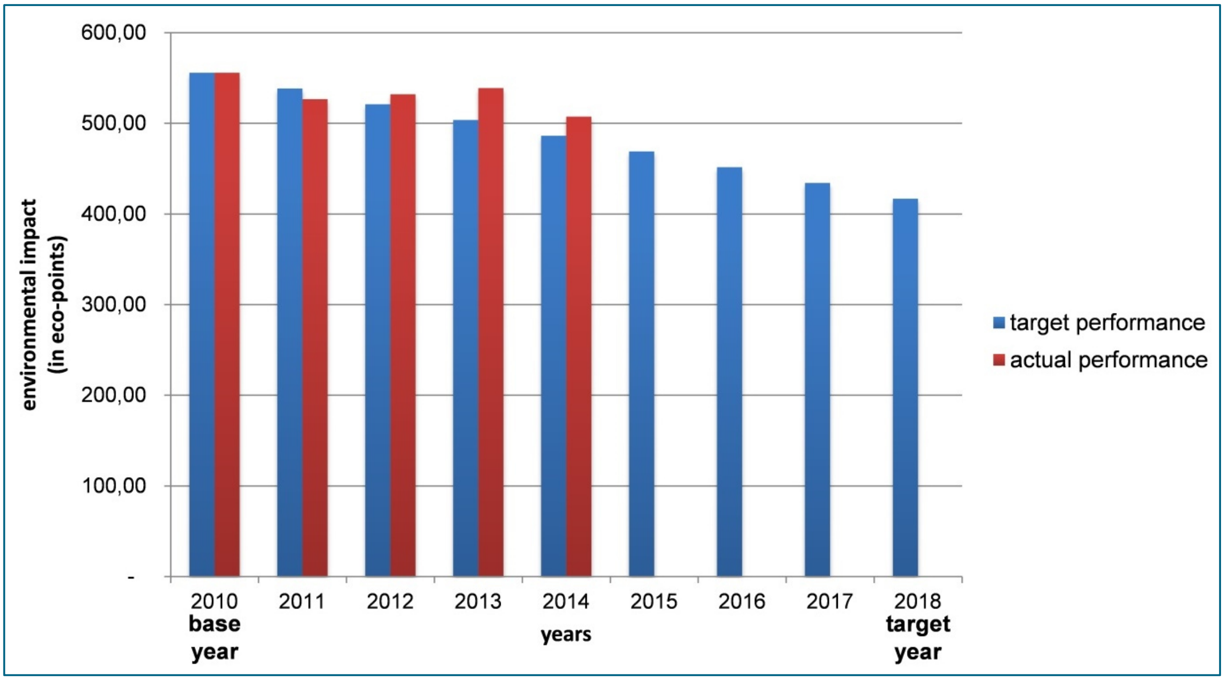
Year	Target env. performance (in eco-points)	Actual env. performance (in eco-points)	Difference target to actual env. performance
2010	555,867.65	555,867.65	
2011	538,496.79	526,703.47	- 2.19%
2012	521,125.92	532,078.99	2.10%
2013	503,755.06	538,961.70	6.99%
2014	486,384.20	507,445.44	4.33%
2015	469,013.33		
2016	451,642.47		
2017	434,271.60		
2018	416,900.74		

Source: Own calculations on the basis of Kitzmann, 2015 [data adjusted according to secret factor]

With the help of the table above, the decision-maker can assess the actual environmental performance against the targeted performance and thus would retrieve the conclusion that the five production sites are lacking behind their target with 4.33 percent difference.

Alternatively, the decision-maker can visualise the targeted and the actual environmental performance in form of bar chart comparison as exemplarily illustrated in the following figure:

Figure 80: Alternative visualisation of targeted and actual environmental performance of the five production sites



Source: Own illustration based on Volkswagen, 2012c and Kitzmann, 2015 [data adjusted according to secret factor]

An alternative way of reporting can comprise the annual reduction budgets instead the total environmental impact data. When reporting this alternative, the difference between the reduction budget and actual reduced eco-points is added or deducted to the reduction budget of the following year in analogy to the rolling budgeting process of management accounting (compare Zimmerman, 2011). The following table provides an overview of this alternative way of reporting environmental performance:

Table 83: Comparison of reduction budgets and actual reduction of the five production sites

Year	Reduction budget (in eco-points)	Actual reduction (in eco-points)	Difference (in eco-points)
2011	17,370.86	29,164.18	- 11,793.32
2012	5,577.55	- 5,375.52	10,953.06
2013	28,323.93	- 6,882.71	35,206.64
2014	52,577.50	31,516.26	21,061.25

Source: Own calculations on the basis of Kitzmann, 2015 [data adjusted according to secret factor]

The reporting along the reduction budgets reveals the total differences which are carried forward to the following year. For instance, the actual reduction in 2011 was way higher than the reduction budget, resulting in a negative budget (i.e. no need for reducing environmental impacts in 2012) for the following year. In contrast to that, the environmental impact increased in 2013 which resulted in an increase of budgeted reduction for 2014.

Feedback and corrective actions

The final step of the environmental management control system of this case study is represented by feedback and corrective actions. Based on the report of the environmental performance within the previous step, the decision-maker knows that the sum of production sites is slightly behind its environmental targets. As a consequence of the rolling budgeting process, 21,061.25 eco-points are added to the annual reduction budget resulting in a total budget of 38,432.11 eco-points which need to be reduced in 2015.

After the first quarter of 2015, it is possible to provide a forecast of the development of measures and the corresponding impacts on the environmental performance of the five production sites. The current situation regarding the amount of measures, their status of implementation as well as the reduced eco-points is depicted in the following table:

Table 84: Overview of the current situation of measures of the five production sites (1st quarter 2015)

Status	Amount	Reduced env. impact (in eco-points)
Status 1	7	116.03
Status 2	28	3,609.95
Status 3	60	8,474.22
Status 4	28	4,537.42
Status 5	51	1,841.32
Sum	**174**	**18,578.94**

Source: Own calculations on the basis of Volkswagen, 2015d [data adjusted according to secret factor]

It is noticeable that there were already a lot of measures realised and the financial effects were verified (i.e. 'status 5') within the first quarter of the year. However, their realisation has started already in the previous year but their environmental impact is not deducted from the total environmental impact of the production site unless the 'status 5' is achieved. Given the reduction budget of 38,432.11 eco-points, the 1,841.32 eco-points which have recently achieved 'status 5' already forecast an under-achievement of the annual environmental goal (see Table 68).

Table 85: Forecast of current annual environmental impact reduction of the five production sites

Year	Annual reduction budget (in eco-points)	New 'status 5'- measures in 2015 (in eco-points)	Difference
2015	38,432.11	1,841.32	36,590.79

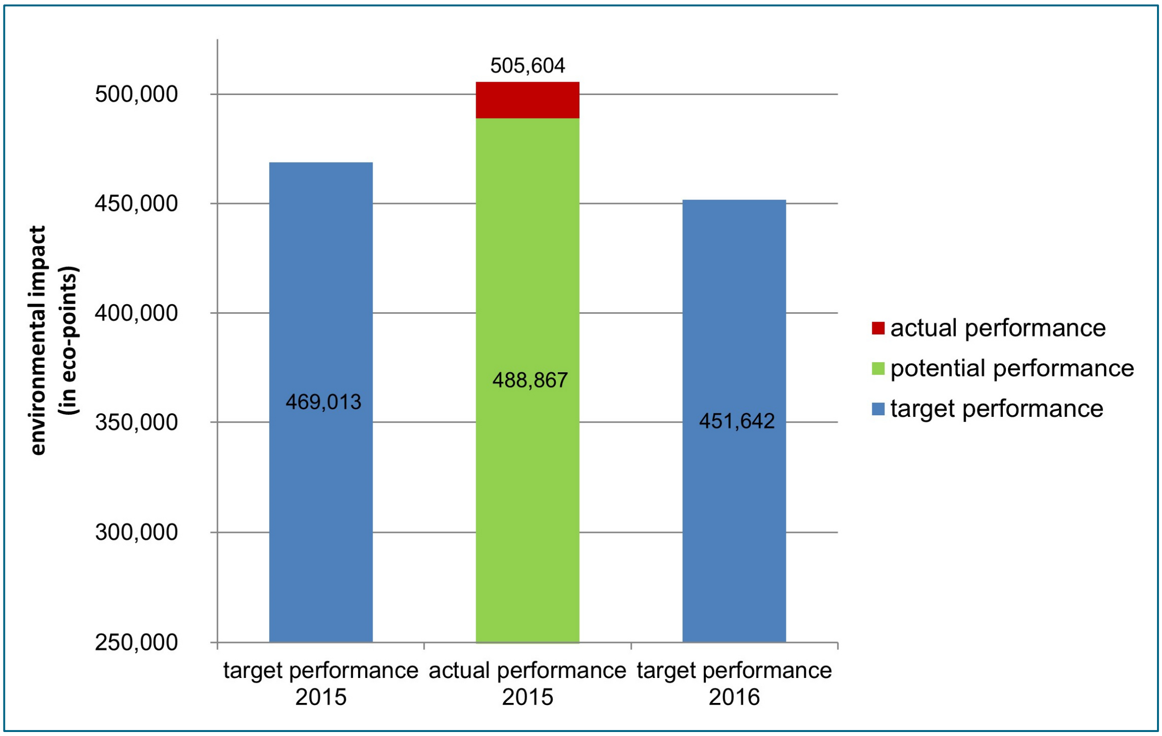
Source: Own calculations on the basis of Volkswagen, 2015d [data adjusted according to secret factor]

There are additional measures with 'status 2', 'status 3' and 'status 4' in the pipeline representing a potential for additional 16,737.62 eco-points that can be deducted from the total environmental impact of the five production sites till the end of the current year. In this case, there is a potential for the total difference of 19,853.17 eco-points, assuming that the management accounting department verifies this potential. As a consequence, the annual reduction budget for 2016 would be 37,224.03 eco-points (17,370.86 eco-points annual reduction budget + 19,853.17 eco-points difference).

With this forecast, the decision-maker knows that the five production sites are not going to meet the annual environmental reduction goal, even if all measures in the pipeline were transferred to 'status 5'. Therefore, the corrective action would be to encourage transferring the measures to 'status 5' as soon as possible. Besides the amount of reduced eco-points, the database also reveals the capital expenditure necessary to realise the investment measures. In this case, the sum of all measures in 'status 1' and 'status 2' is about 199,300,182 Euro (value was adjusted). Regarding the measures with 'status 3' and 'status 4', the investment decision has already taken place, so the decision-maker has to focus on transferring these measures to 'status 5' as soon as possible.

The amount of actually reduced eco-points can be deducted from the actual environmental performance of the previous year in order to derive a forecast of the actual environmental performance of the year 2015. Furthermore, potentials can be visualised by additionally deducting the saved eco-points of all measures with 'status 1' to 'status 4'. To provide additional orientation for the decision-maker, these two amounts are set in relation to the target value of the upcoming year. The forecast of actual, potential and targeted amounts of the five production sites can be retrieved in the following figure:

Figure 81: Forecast of actual, potential and targeted environmental performance of the five production sites



Source: Own illustration based on Volkswagen, 2012c and Volkswagen, 2105d [data adjusted according to secret factor]

Additional corrective action in this step might comprise encouraging employees and management to search for additional measures so that new measures can be generated. This encouragement would ensure that there are sufficient measures over which their implementation can be decided in 2016 in order to reach the environmental goal of the subsequent year. Furthermore, a target value for these measures can be set at a minimum of 37,224.03 eco-points since this is going to be the reduction budget for 2016 in case all remaining measures are realised and transferred to ‘status 5’ in 2015.

5.4. Cross-case synthesis

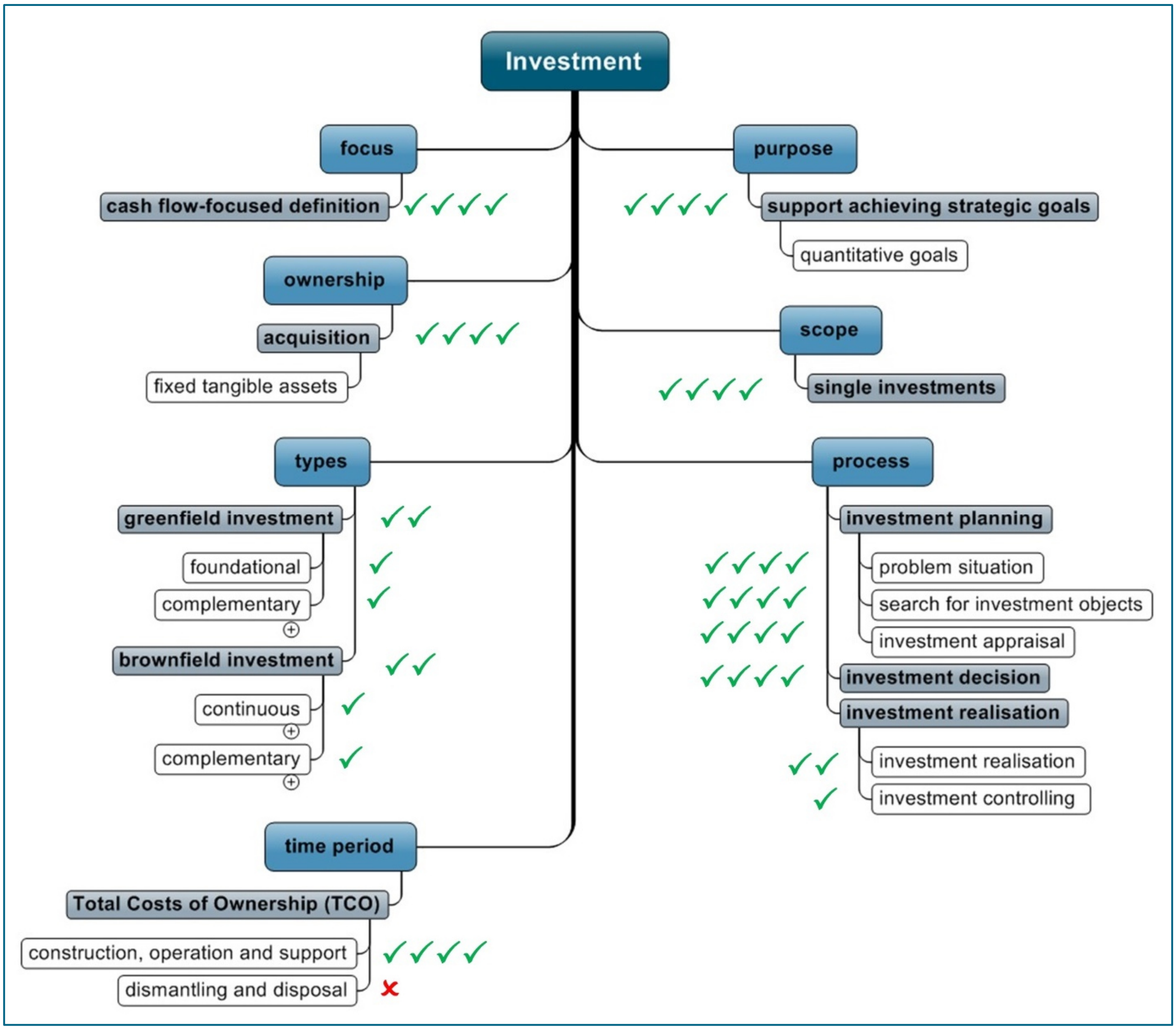
This chapter intends to analyse the case studies of the previous subchapters in order to draw generalizable conclusions in form of propositions. This analysis is examined via cross-case synthesis due to the replication logic underlying the chosen holistic multiple-case study design in the context of this thesis. In addition, this chapter is separated into two parts since one part focuses on single investments and intends to provide answers to the first case study research question, while the second part focuses on investment programs and aims intends to answer the second case study research question.

5.4.1. Cross-case synthesis of case studies on single investments

The cases within this subchapter deal with the application of the integrated investing method in real investment cases. Hence, the aim of these cases is to answer the first case study research question, that intends to identify problems and limitations during application as well as the type, origin and severity of the identified problems.

Therefore, the method of cross-case synthesis summarises and compares the cases along specific characteristics in order to draw conclusions regarding any occurring problems during method application. Regarding the characteristics of the summarising and comparing table, the characteristics and attributes of the unit of analysis represent a helpful structure. The following figure provides an overview of characteristics and attributes of all single investment cases of this thesis:

Figure 82: Overview of the characteristics and attributes of single investment case studies within this thesis



Source: Own illustration

Figure 82 reveals that all four single investment cases of the previous subchapter share the same attributes regarding the focus, purpose, ownership, scope and time period. Due to the reasoning for selecting the cases, there are two cases dealing with greenfield investments and two cases concerning brownfield investments. Furthermore, all cases share the first four steps of the investment process. However, only two cases comprise the investment realisation phase and only one case includes the investment controlling phase.

As a consequence, the characteristics of the subsequent table, which summarises and compares the cases, include the characteristics in which the four cases differ from each other. Hence, these characteristics comprise the investment phases but also the types of the cases. In addition, the context of each case is different while sharing the overarching context of automobile manufacturing within the Volkswagen Group. Therefore, the following table summarises and compares the four single investment case studies:

Table 86: Cross-case synthesis of single investment cases within this thesis

Category	Case 1 New cylinder head production	Case 2 Retrofit of a transfer press	Case 3 New construction of a body shop	Case 4 New paint shop on a greenfield site
Context of case study	context - components production characteristics - mechanical processing steps - series of machines from rough operations to finish operations with initial washing steps - medium environmental relevance	context - press shop characteristics - batch production of body shop parts - low downtime and high throughput rates - avoid interruption of subsequent body shop production - medium environmental relevance	context - body shop characteristics - high automation rate - robots are structured in cells - differentiation between welding and geometry stations - medium environmental relevance	context - paint shop characteristics - high investment needs and long-term operations - paint application is a long and complex process with strict processing parameters - low amount of paint shop suppliers for automotive industry - high environmental relevance
Type of investment	greenfield investment - complementary - expansion	brownfield investment - continuous - retrofit	brownfield investment - complementary - diversification	greenfield investment - foundational
Problem situation phase	reason - capacity expansion to meet demand in a world region	reason - expiring service of spare parts delivery due to old age of the press - risk of long downtimes and interruption of subsequent body shop production	reason - introduction of new car model with new platform (modular transverse matrix)	reason - expiring contract about joint production with a business partner - necessity to build own production site

Category	Case 1 New cylinder head production	Case 2 Retrofit of a transfer press	Case 3 New construction of a body shop	Case 4 New paint shop on a greenfield site
Problem situation phase (cont.)	current situation - no representation of current situation due to lack of data - no expression of eco-points - no expression of environmental impact in a flow model desired situation - primary aim: build at least according to current state of the art - secondary aim: keep environmental impact as moderate as possible - no quantified targets available	current situation - electricity and compressed air can be measured - consumption of oil, lubrication and waste production cannot be measured - expression of environmental impact in a flow model desired situation - primary aim: retrofit transfer press with a new powertrain for which spare part delivery is guaranteed - secondary aim: reduce resource consumption - no quantified targets available	current situation - electricity, heat, fresh water, cooling water, compressed air can be measured - waste and air emissions cannot be measured - expression of environmental impact in a flow model desired situation - primary aim: ensure future production capacity and enable production of various future car models - secondary aim: radically decrease energy consumption - no quantified targets available	current situation - no representation of current situation due to lack of data from joint production - no expression in eco-points - no expression of environmental impact in a flow model desired situation - primary aim: build a paint shop beyond current state of the art - secondary aim: keep environmental impact as moderate as possible - no quantified targets available
Search for alternatives phase	alternatives - mechanical processing steps keep the same due to nature of cylinder head - comparison of two lubrication techniques ○ cooling lubrication ○ minimum lubrication	alternatives - no search for alternatives conducted due to cooperation with manufacturer of the transfer press	alternatives - no search for alternative due to level of analysis ○ one piece of key-ready body shop ○ internally reported as one project	alternatives - two main competitors on the market with similar offers - comparison of two overspray treatment techniques ○ binding in waste water ○ binding in rock flour

Category	Case 1 New cylinder head production	Case 2 Retrofit of a transfer press	Case 3 New construction of a body shop	Case 4 New paint shop on a greenfield site
Search for alternatives phase (cont.)	data availability - forecast of resource and emission flows - forecast of eco-points - visualisation of eco-points	data availability - forecast of resource and emission flows - forecast of eco-points - visualisation of eco-points	data availability - forecast of resource and emission flows - forecast of eco-points - visualisation of eco-points	data availability - forecast of resource and emission flows - forecast of eco-points - visualisation of eco-points
Investment appraisal phase	- no data for PBP, ROI and NPV available - capex and opex available - environmental impact calculated for both techniques - eco-efficiency indicators can only be calculated for one alternative	- no data for PBP, ROI and NPV available - capex and opex available - environmental impact calculated - eco-efficiency indicators can be calculated	- no data for PBP, ROI and NPV available - capex and opex available - environmental impact calculated - eco-efficiency indicators can be calculated	- no data for PBP, ROI and NPV available - capex and opex available - environmental impact calculated for both techniques - eco-efficiency indicators can be calculated for one alternative
Investment decision phase	- no financial and environmental budgets available - map available, state of the art as reference point - utility value analysis with three indicators ○ capex ○ opex ○ environmental impact - all indicators point towards minimum lubrication as most advantageousness - decision to invest in minimum lubrication	- no financial and environmental budgets available - map available, current situation as reference point - no utility value analysis necessary due to lack of alternatives - decision to conduct retrofit measure	- no financial and environmental budgets available - map available, current situation as reference point - no utility value analysis necessary due to lack of alternatives - decision to conduct construction of new body shop	- no financial and environmental budgets available - map available, state of the art as reference point - utility value analysis with three indicators ○ capex ○ opex ○ environmental impact - all indicators point towards supplier b as most advantageousness - decision to invest in supplier b

Category	Case 1 New cylinder head production	Case 2 Retrofit of a transfer press	Case 3 New construction of a body shop	Case 4 New paint shop on a greenfield site
Investment realisation phase	not available	- no additional metering points installed – not necessary - no coherence test of metering point with IT-infrastructure necessary - no record of delivery available	- over 500 additional metering points for analysis of all relevant energy consumers - calibration and implementation in IT-infrastructure currently in progress - no record of delivery available	not available
Investment controlling phase	not available	- comparison of situation before and after retrofit with the forecasted situation - all actual resource flows below forecast – except compressed air (12 bar)	not available	not available

Source: Own representation

Context and types of investments

When comparing these four cases, it is obvious that every case provides the application of the integrated investing method in another context, while each context shows different characteristics. In addition, it is noticeable that two cases represent brownfield investments and two cases deal with greenfield investments. However, there are different attributes within the same characteristics. For instance, while one greenfield investment is concerned with a complementary investment aiming to expand local production capacities, the other greenfield investment is characterised by a foundational investment moving the production from a joint production with a business partner to an own newly constructed site.

Problem situation

The categorisation of the type of investment is a consequence of the reason describing the investment need within the beginning of the problem situation phase. These reasoning differ widely amongst the cases. While in two cases an expiring contract or a service represents the reason for an investment, the other two cases comprise an introduction of a new car model platform and an expansion of production capacities as reasons.

Besides a summary and comparison of the four cases, this subchapter intends to identify problems within the application of the integrated investing method. One common problem within the problem situation phase deals with the description of the actual situation. While there are no resource and emission flow data available in the greenfield case studies, the brownfield cases face the problem of data completeness. Whereas electricity, heat, compressed air, fresh and cooling water can be measured, there is no measurement or documentation system for waste or air emissions. Although the environmental impact can be determined and illustrated in form of eco-points based on the measured data, it is necessary to assess whether all relevant environmental aspects are taken into consideration.

Regarding the description of the desired situation, it is noticeable that in all cases the primary aim is connected to the reason and the characteristics of the context. Moreover, the secondary aim is to keep the environmental impact as moderate as possible in the context of the greenfield investments and to decrease resource or energy consumption in the context of brownfield investments. Nevertheless, in all cases, the provided aims in the description of the desired situation do not comprise a quantifiable target. Hence, it is questionable whether the problem situation phase is too early to formulate precise and quantifiable targets.

Search for alternatives

The amount of competing investment objects differ between greenfield and brownfield investments. While there are no competing investment objects for brownfield investments due to the complexity and the individuality of the current asset in place, the greenfield cases each comprise two competing investment objects. Concerning these two investment alternatives, one object can be classified as state of the art whereas the remaining object is classified as innovative or best available technology.

However, all cases comprise forecasts of resource and emission flows as well as their corresponding environmental impacts in form of eco-points. In addition, all cases contain a visualisation of forecasted eco-points in form of bar and pie charts. Hence, besides the problem of researching an appropriate amount of competing investment objects, the data availability of forecasted resource and emission flows as well as the expression and visualisation in form of eco-points do not lead to any problems in application.

Investment appraisal

This phase reveals the similarity that all cases lack the financial indicators PBP, ROI and NPV. The reasons for such a significant lack of important data are manifold. On the one hand, it is difficult (but not impossible) to calculate imputed income from savings especially for greenfield investments. On the other hand, however, these indicators might not comprise a significant basis for investment decisions since two cases show no alternative and the other two cases show a strategic character. An additional reason might also be the sensitivity of such information resulting in efforts to keep these indicators confidential.

Nevertheless, financial data in form of capital and operational expenditure is available for all cases as well as environmental impact data in form of eco-points. Nonetheless, when calculating the eco-efficiency indicators, the lack of competing investment objects in the context of greenfield investments result in the inability to calculate these indicators for one investment object. In both greenfield cases, the eco-efficiency indicator is calculated for the innovative technology taking the current state of the art technology as the reference value. Regarding the brownfield investment cases, all indicators can be calculated since the current situation functions as the reference value.

Investment decision

In all case studies, the map containing an overview of environmental and financial performance of the competing investment object can be represented. Yet, due to the lack of environmental and financial budgets for the business unit or the investment decision under consideration, the reference point in the middle of the map must alternatively be determined. In the context of the greenfield investments, the reference point is determined by taking the environmental and financial performance of the current state of the art. In contrast to that, the environmental and financial performance of the current situation is taken as reference point for both brownfield investments. As a consequence, in all cases, the problem of missing environmental and financial budgets can be overcome by alternative determinations, enabling to provide a visual overview of competing investment objects.

In addition, the integrated investing method suggests the calculation of a utility value to determine the relative advantageousness of the competing investment objects. While there is no utility value calculated within the brownfield investment cases due to a lack of investment alternatives, the utility values within the greenfield investment cases comprise capital expenditure, operating expenditure and the environmental impact in form of eco-points. In these cases, the weighting factors need to be adjusted to ensure an equal weighting between financial and environmental indicators. However, in both greenfield investment cases, all indicators identify the same object as advantageous. Hence, the utility value analysis is obsolete in these cases but is exemplarily calculated in the case studies.

Investment realisation

Since the investment objects within the two greenfield investments are currently under construction, the investment realisation phase cannot be described for these cases due to a lack of available data. Nevertheless, the two brownfield investment cases also comprise the investment realisation phase. While there are over 500 additional metering points installed within the body shop case study, the press shop case study does not contain the installation of additional metering points since a more detailed analysis would not comprise any additional insights.

Therefore, the coherence with the IT-infrastructure does not need to be tested regarding the press shop case study, whereas the implementation of the 500 additional metering points is currently in progress in the context of the body shop case study.

In addition, both case studies do not provide a record of delivery. With this suggestion, the integrated investing method intends to provide a basis for comparing forecasted resource and emission flows with actual resource and emission flows. In case of deviations of actual performance to requested performance, as described in the specifications sheet, this record of delivery provides an additional basis for optional legal claims. Yet, this opportunity is foregone by the lack of this record of delivery in both case studies.

Investment controlling

The press shop case study is the only case study comprising the final investment controlling phase. In this phase, the resource and emission flows as well as capital and operating expenditure after realisation of the retrofit measure can be compared to the forecasted data and the situation before the retrofit measure. This comparison reveals that the actual performance after the realisation of the measure turns out to be better than expected, except the consumption of compressed air (12 bar). As a consequence, the operating and maintenance personnel is currently analysing the reasons for such an unexpected increase. This behaviour shows the importance of this phase and reveals necessity of applying the integrated investing method, since deviations in resource and emission flows would not be tracked without this method.

5.4.2. Cross-case synthesis of case studies on investment programs

The cases within this subchapter deal with the application of the integrated investing method in real investment programs. Hence, the aim of these case studies is to answer the second research question that intends to identify the method's ability to manage and control strategic environmental goals.

Therefore, the method of cross-case synthesis summarises and compares the cases along specific characteristics in order to draw conclusions regarding any occurring problems concerning the management and control of environmental goals. Regarding the characteristics of the summarising and comparing table, the steps of the environmental management control system are illustrated in Figure 41. Consequently, the following table summarises and compares the three case studies on management and control of environmental goals via investment programs:

Table 87: Cross-case synthesis of investment program cases within this thesis

Category	**Case 1** **one business unit**	**Case 2** **one production site**	**Case 3** **five production sites**
Context	technical development business unit	production site including car manufacturing and components production	five production sites including car manufacturing and components production
Input in form of environmental goals	current environmental goals - absolute reduction of energy and emissions of 25 percent ○ base year – 2010 ○ target year – 2018 environmental goals for the case study - transfer to the eco-points indicator possible - only energy consumption considered to avoid double-counting of air emissions - Input: 25 percent reduction in eco-points ○ base year – 2010 ○ target year – 2018	current environmental goals - relative reduction of five KPIs of 25 percent ○ base year – 2010 ○ target year – 2018 environmental goals for the case study - transfer to the eco-points indicator possible - absolute reduction instead of specific reduction to avoid volume effect - adaptations to avoid double-counting of air emissions - input 25 percent reduction in eco-points ○ base year – 2010 ○ target year – 2018	current environmental goals - relative reduction of five KPIs of 25 percent ○ base year – 2010 ○ target year – 2018 environmental goals for the case study - transfer to the eco-points indicator possible - absolute reduction instead of specific reduction to avoid volume effect - adaptations to avoid double-counting of air emissions - input 25 percent reduction in eco-points ○ base year – 2010 ○ target year – 2018
Process via realisation of investments	database of planned and realised investments - financial performance data - environmental performance data	database of planned and realised investments - financial performance data - environmental performance data	database of planned and realised investments - financial performance data - environmental performance data

Category	Case 1 one business unit	Case 2 one production site	Case 3 five production sites
Process via realisation of investments (cont.)	overview over current situation of investments available - amount of investment projects: 134 projects in total - status of implementation ○ 33 planned projects ○ 12 decided projects ○ 89 realised projects - capital expenditure ○ 162,333.10 € in total - reduced environmental impact ○ 4,651.66 eco-points in total	overview over current situation of investments available - amount of investment projects: 223 projects in total - status of implementation ○ 11 planned projects ○ 28 decided projects ○ 45 realised projects ○ 139 rejected projects - capital expenditure ○ 2,797,170.98 € in total - reduced environmental impact ○ 95,155.10 eco-points in total	overview over current situation of investments available - amount of investment projects: 393 projects in total - status of implementation ○ 35 planned projects ○ 60 decided projects ○ 79 realised projects ○ 219 rejected projects - capital expenditure ○ 3,239,019.90 € in total - reduced environmental impact ○ 106,447.15 eco-points in total
Output in form of environmental performance measurement	- historic development of environmental performance assessable - comparison of projected and actual environmental performance of past year, only + 0.27 percent deviation - alternative way of comparison in form of environmental budgets possible ○ identifying an annual reduction target of 763.76 eco-points ○ only 58.18 eco-points reduced too less in past year	- historic development of environmental performance assessable - comparison of projected and actual environmental performance of past year, only +1.05 percent deviation - alternative way of comparison in form of environmental budgets possible ○ identifying an annual reduction target of 7,729.37 eco-points ○ 2,281.94 eco-points reduced too less in past year	- historic development of environmental performance assessable - comparison of projected and actual environmental performance of past year, + 4.33 percent deviation - alternative way of comparison in form of environmental budgets possible ○ identifying an annual reduction target of 17,370.86 eco-points ○ 21,061.25 eco-points reduced too less in past year

Category	Case 1 one business unit	Case 2 one production site	Case 3 five production sites
Feedback and corrective actions	reduction budget for the current year 2015 of 821.94 eco-points overview of investment projects for the current year - 54 projects investment projects in total - status of implementation ○ 2 planned projects ○ 3 decided projects ○ 49 realised projects forecast of environmental performance of current year possible - including realised projects : - 520.34 eco-points - including planned and decided projects : - 573.42 eco-points forecast of reduction budget for future year - 190.29 eco-points to be reduced	reduction budget for the current year 2015 of 10,011.21 eco-points overview of investment projects for the current year - 84 investment projects in total - status of implementation ○ 11 planned projects ○ 28 decided projects ○ 45 realised projects forecast of environmental performance of current year possible - including realised projects : +8,829.07 eco-points - including planned and decided projects: - 2,177.23 eco-points forecast of reduction budget for future year - 5,552.04 eco-points to be reduced	reduction budget for the current year 2015 of 38,432.11 eco-points overview of investment projects for the current year - 174 investment projects in total - status of implementation ○ 35 planned projects ○ 60 decided projects ○ 79 realised projects forecast of environmental performance of current year possible - including realised projects : +36,590.79 eco-points - including planned and decided projects: + 19,853.17 eco-points forecast of reduction budget for future year - 37,224.03 eco-points to be reduced

Category	Case 1 one business unit	Case 2 one production site	Case 3 five production sites
Feedback and corrective actions (cont.)	Corrective action - encouragement of employees to generate new measure suggestions	Corrective action - encouragement of employees to generate new measure suggestions - realisations of projects currently under construction - decide about new projects and provide necessary capital expenditure	Corrective action - encouragement of employees to generate new measure suggestions - realisations of projects currently under construction - decide about new projects and provide necessary capital expenditure

Source: Own representation

When comparing the three cases summarised in the table above, each case shows a different context and degree of detail and aggregation. While the case study in the context of the business unit represents the smallest scope of consideration, the case studies regarding one production site and the summary of five production sites show a broader scope of consideration. Nevertheless, the management control process in form of input, process, output as well as feedback and corrective action is the same in all three case studies.

Input in form of environmental goals

All three goals show similar reduction goals with similar base and target years. However, the business unit case differs regarding the scope of consideration. While the technical development represents a non-production function, the environmental goals only comprise a reduction of 25 percent in energy and air emissions (CO_2-equivalents). In contrast to that, the environmental goals of the production sites (‘case 2’ and ‘case 3’) also comprise a reduction of 25 percent in energy, air emissions (CO_2-equivalents) but in addition a reduction of VOC-emissions, waste and fresh water consumption. While the environmental goals for the technical development business unit are expressed in absolute amounts, the environmental goals in the context of the other two case studies are expressed in relative values. Hence, the values are expressed in environmental aspects per manufactured car or produced component.

However, the environmental goals of all case studies can be transferred to the eco-points indicator via multiplication of the environmental aspects with the corresponding eco-factors. In this context, the CO_2-equivalents are excluded from the calculation to avoid double-counting since they are already included in the eco-points caused by energy consumption. The subsequent step comprises an aggregation of all eco-points into a total amount of eco-points which needs to be reduced by 25 percent till 2018. In the context of the two production sites cases, the assumption is to express the environmental goals in absolute figures to circumvent the problem of the unknown impact of the ‘volume effect’ on the development of environmental performance.

Process via realisation of investments

All considered cases share the same database in which investment projects are listed and tracked. This database aims to enhance knowledge and experience exchange amongst the production sites and business units. Nevertheless, the database can also provide an overview of the current situation of investments of the business unit or production site.

The database is able to list the amount of investment projects, their status of implementation, as well as their reduction of environmental aspects and their capital expenditure. The reduction of environmental aspects can be transferred to the eco-points indicator in order to assess the impact on the environmental performance of the unit of analysis.

It is possible to provide such an overview of investment projects for all three case studies. In addition, the total amount of investment projects, their total amounts of capital expenditure and reduced eco-points increase with an increase of the cases' scopes. On the one hand, this shows the plausibility of underlying data within the database and the possibility of aggregating environmental and financial performance on the other hand.

Output in form of environmental performance measurement

All three cases provide an overview of historic development of environmental performance from the start of the environmental goals in 2010 till the past year 2014. This historic development overview helps the decision-maker to set the environmental performance of the past year in a historic context. Hence, the management can assess whether the performance of the past year is better or worse compared to the previous year(s).

In addition, the environmental performance of the past year can be set in context to the targeted environmental performance of the same year. This ideal environmental performance is calculated by annually deducting 3.125 percent from the eco-points of the base year. In all three cases, the deviations between ideal and actual performance can be presented, providing an additional basis of analysis for the decision-maker.

Furthermore, an alternative way of assessing the environmental performance of the past year is to calculate with reduction budgets which are expressed in form of eco-points. In all three cases, the difference between ideal and actual amounts of reduced eco-points can be expressed and rolled over to the budget of the subsequent year. As a consequence, the management in each case study is able to express the remaining reduction budget in an amount of eco-points which provides a valuable basis for the subsequent step of the environmental management control system.

Feedback and corrective action

In all three cases, the rolling budget in form of remaining eco-points to be reduced from the previous year is added to the annual reduction budget. This provides the annual target of eco-points which need to be reduced. For all three cases, it is possible to derive a forecast of the impact on environmental performance of the current situation of investment projects from the database.

While this forecast reveals that the annual reduction budget is going to be kept in the context of the business unit case study, the case study of the single production site reveals that already decided investment projects need to be transferred to ‘status 5’ to meet the annual reduction budget. In contrast to this, the case study regarding the five production sites, reveals in this phase the information that the sum of planned, decided and realised investment projects is not enough to meet the annual reduction budget. Nevertheless, in all three cases it is additionally possible to forecast the impact of current investment projects on the annual reduction budget of the subsequent year.

Besides these forecasts, the decision maker is able to draw corrective actions which function as input on the current process in form of realisation of investments. All three cases share the same corrective action of encouraging employees to suggest new investment measures in the database. Regarding the two case studies in the context of the production sites, additional corrective actions intend to transfer more investments to ‘status 5’ so that they are accounted as reduced environmental impact and to decide about new investments while providing the corresponding capital expenditure.

5.5. Summary and discussion of the method application

Summary

This method application chapter is sub-divided into four parts. The first part deals with the case study research design which specifies the framework of research methodology. Hence, research objectives and research questions were determined as well as the unit of analysis. Furthermore, the rationale behind the selection of cases for detailed research is explained and appropriate methods of data collection and data analysis are discussed. Finally, a standardised layout of the case study report is defined in form of the case study protocol.

The second part comprises a short description of the Volkswagen Group and its investment processes before the third part is represented by seven case study reports. These seven case study reports are split into two groups. The first group comprises four case studies, which are structured along the automobile manufacturing process, consisting of single investments, which aim to identify any problems regarding the integrated investing method’s practical applicability. The results reveal that not all suggested steps must be performed to successfully integrate environmental impacts in investment decisions. The converse argumentation holds that the integrated investing method still works even if not all suggested steps in each investment phase can exactly be performed. However, the results also identify the research of a sufficient amount of competing investment alternatives as important part within the integrated investing method to calculate the eco-efficiency indicators.

The second group comprises three cases, which are structured along an environmental management control system, consisting of investment programs which aim to identify the ability of the integrated investing method to manage and control environmental goals besides financial goals.

The result reveals that the cases prove the ability to manage and control strategic environmental goals of a company. The impact of the investment program on the current environmental performance as well as the forecasted impact of corrective actions are possible when basing the environmental management and control system on the eco-points indicator.

Discussion

There are several limitations involved within the method application chapter which can be structured along the case study research design as well as the cases on single investments and investment programs in the context of the execution of case study research.

Case study research design

Regarding the case study research design, one limitation focuses on the context of the cases, since all case studies deal with the application of the integrated investing method at one automobile manufacturer. Hence, the concluding limitation addresses the limited generalisability of the case study findings. Nevertheless, each case comprises a different detailed context, represented by the automotive production process, while sharing one context, which is the automotive OEM Volkswagen. On the one hand, the findings reveal that the applied context does not have a significant impact on the case study but rather the type of investment (i.e. greenfield or brownfield investment). On the other hand, the Volkswagen Group, as one of the leading automobile manufacturer worldwide, represents a broad basis for the generalisability of results at least for the automotive industry. An additional argument in this context is the high degree of automation and standardisation of the automobile manufacturing process. Hence, the core processes are similar throughout the automotive industry.

An additional limitation regarding the case study research design addresses the selection procedure of the case studies. While the selection of single investments is executed along the core automobile production processes and the differentiation between greenfield and brownfield investments, all available cases regarding investment programs are selected due to absence of alternatives. Again, the limitation addresses the findings of the investment program case studies, which might have been different, if other cases would have been available, requiring a similar selection procedure in analogy to the selection procedure of single investments. Nevertheless, the intention of the investment program case studies is to verify the ability to manage and control environmental goals. The three cases verify the ability on three different levels of control (i.e. business unit, one production site, five production sites). Considering the fact that the organisational structure is similar throughout the Volkswagen Group, additional case studies or a different selection procedure might not have revealed different findings.

Further limitations address the data collection within the case study research design. The dependency on secondary data provokes the problem that the data was originally collected to serve a different purpose. Hence, realised investment processes which are adapted according to the integrated investing method are originally not conducted with the intention to serve strategic environmental goals. Instead, the main aims are rather to ensure technical feasibility, avoid downtime or to ensure the planned production volumes and required quality specifications. Hence, the investment decision has also originally been taken with the intention to serve these environmental aims.

Finally, the method of data analysis comprises its limitations as well. These limitations contain the choice of the analysis method as well as its execution. While the holistic multiple case study approach already indicates the use of a cross-case synthesis due to the availability of multiple cases, another analysis method might have been chosen as well. In addition, the characteristics on which the cross-case synthesis is executed might have been chosen differently concluding possible alternative results.

Case studies on single investments

The main limitations regarding the case studies on single investments deal with the underlying resource and emission flow data but also the persons involved as well as their responsibilities. With regard to the resource and emission flow data, the limitations deal with the origin of data, its quality as well as the comparability of resource and emission flows.

Regarding the origin of the data, the supplying company forecasts the resource and emission flows, based on the specification sheet, which is provided by the technical planning department of Volkswagen. Since the supplying company is aware of the fact that it is competing with other supplying companies for the deal, there are incentives of forecasting low resource and emission flows. Hence, there is the risk that actual resource and emission flows are higher than forecasted resource and emission flows. However, while the high bargaining power of some monopoly suppliers (e.g. for transfer presses) hinder the disclosure of resource and emission flows of the supplied investment objects, other supplying companies are simply not able to disclose such information.

As a consequence, it is difficult for the technical planning department to gather precise information of resource and emission flows and to conduct a fair validity check of the disclosed data. In addition, the planner is only able to conduct a rough validity check by comparing the disclosed data with similar machines that are already under operation. However, most machines are not equipped with own metering points so that a precise measurement and comparison is impossible. In addition, the newly planned machine is expected to outperform the old machine anyway due to natural improvement of the current state of the art. Hence, for a fair validity check, the planner has to conduct a benchmark with all competing supplying companies. Nevertheless, even with standardised specification sheets, the practical application shows that the scope and quality of disclosed data varies widely between the suppling companies. As a consequence, the planner is faced with increased effort of establishing a fair validity check which can – at best – only serve as rough orientation. Unfortunately, this kind of benchmark validity check is not possible in cases in which there is no alternative investment object available.

Another limitation in the context of the data collection focuses on the completeness of actual performance data. In this context, resource and emission flows lack completeness in some case studies due to a lack of metering points or other documentary systems. While the consumption of electricity, heat or compressed air is measured comprehensively, due to their cost relevance, other resource and emission flows are only measured on a plant level. For instance, the air emissions as well as waste water emissions are measured or calculated via an end-of-pipe approach. However, these resource and emission flows are not allocated to their pollution sources. As a consequence, the scope of resource and emission flow data and their quality vary not only between the different case studies but also between the resource and emission flows under consideration. In nearly all case studies, there were resource and emission flows which could not be measured at all and therefore are excluded from the environmental impact assessment.

Besides the limitations regarding the resource and emission flow data, the financial data also comprises its limitations. Hence, the cost data mostly includes the costs for the supply of resources (i.e. electricity, water, heat, etc.) but lack additional operating costs such as personnel, maintenance or financing costs. In addition, the lack of the NPV also reveals the lack of depreciation or the consideration of the time value of money involving the use of a discount factor. Nevertheless, regarding the lack of data collection, the investment case studies are calculated taking the same scope of collected data into consideration for all competing investment objects to ensure a fair investment appraisal. Another aspect for critical discussion concerns the investment process, the employees involved as well as their responsibilities. In order to apply the integrated investing method, several employees have to contribute different data. While the technical planner is concerned with resource and emission flow data, the management accounting professional is responsible for the financial data comprising the initial capital investment but also the operating costs. In addition, the environmental management representative and the media supply planner contribute their feasibility statements.

Afterwards, the executive manager adds qualitative data for the investment decision. After the investment decision has taken place, the procurement department starts negotiating and purchasing the equipment. The realisation is attended by the technical planning department and by the environmental management representative, in case additional metering points are installed, before the investment object is finally handed over to the operating personnel. A representation of the investment process and the involved employees can be retrieved in Figure 46.

The problem regarding the involvement of the different employees mainly causes from the fact that the involved employees do not cooperate simultaneously but rather successively. Furthermore, the underlying responsibilities differentiate from each other as the following table shows:

Table 88: Overview of departments and their responsibilities in the investment process at the Volkswagen Group

Department	Responsibility
Technical planning	Identify technically feasible investment objects
Environmental management	Avoid violation of given threshold values
Media supply planning	Ensure sufficient media supply of investment object
Management accounting	Conduct investment appraisal, keep within budget
Executive management	Take investment decision
Procurement	Buy the cheapest investment object
Operating personnel	Operate investment object

Source: Own representation

As a consequence, the technical planning might identify the best investment object (Object A), due to technical reasons. The environmental management representative might veto against it due to expected violations of given threshold values and thus identifies another investment object as best alternative (Object B). The executive manager, however, is also influenced by qualitative information such as expected political decisions and therefore decides to invest in another alternative (Object C). Afterwards, the procurement starts negotiating and identifies another supplying company as offering the alternative with the lowest initial capital investment need and hence purchases yet another object (Object D). This example, which happens in practice – albeit in weakened form – intends to show the disadvantage of a successive investment process. A hint for the existence of this problem can be seen in the lack of investment controlling phases throughout the case studies. Therefore, it is necessary that all involved departments need to work in a simultaneous sequence, for instance, in form of a so-called 'operational investment committee'. Within project meetings, every involved department can point towards its responsibilities with the shared goal of finding a consensus regarding the best available investment object. Another advantage is that it is easier to conduct the investment controlling phase in which all involved parties have to reflect on the past investment project in order to identify the lessons learned, which are relevant for everybody.

Case studies on investment programs

The first limitation, to discuss in context of the case studies on investment programs, concerns the input in form of environmental goals. While the case studies on investment programs assume an absolute reduction of total environmental impact, as expressed in eco-points, by 25 percent in eight years, relative figures on basis of the production volumes are ignored. The underlying argumentation is the inability of identifying the 'volume effect' of allocating base loads to the produced items. Nevertheless, the production volumes were constantly rising in the time frame of the case studies so that the efficiency can also be determined via absolute figures. However, in case, the production volumes are decreasing, absolute figures would represent misleading inputs for environmental goals since these can also be reached without increasing production efficiency.

Another aspect for critical discussion is the focus on the process via realisation on investments. Since this focus ignores the existence of organisational measures, which do not need capital expenditure, it is not exactly clear how much impact on the actual environmental performance is caused by investments and how much impact is caused by organisational measures. Hence, these organisational measures should also be part of the shared environmental information system so that the decision-maker is faced with a comprehensive basis, representing the operational reality and its corresponding environmental performance.

An additional limitation is concerned with the interface between the information system and the MCS. On the one hand, the environmental information system contains the aggregated resource and emission flow data and thus, is able to provide a comparison of actual and targeted environmental performance. On the other hand, the forecasts which are generated within the controlling system, base on different database which contains environmentally relevant investment projects. While the resource and emission flow data which is entered into the environmental information system, is based on a group-wide standard (VW 98000), there is no standard for data entered into the investment database. As a consequence, the amount and quality of measures varies between business units and production sites. Since responsibilities are not clearly documented, the maintenance of measures is overdue in some business units and production sites. In context of this thesis, the author only referred to the business units and production sites with the highest amount, quality and up-to-datedness within this database.

Another consequence of the missing standardisation within the investment database is the fact that the management accountant is responsible for approving ‘status 5’ (financial effect verified) which also represents the first validity check within this database. However, the management accountant lacks technical expertise and therefore, is able to only conduct a rough assessment of the cost-relevant resource and emission flows. In case no metering points were installed either for the old machine or the new investment object, a verification of reduced resource and emission flows is nearly impossible. Hence, the management accountant can only concentrate on the coherence of the calculations, which are provided by the technical planning department, in order to verify the financial effects of the measure.

Therefore, the forecasted effects from the investment database of the controlling system will not directly be mirrored in the shared environmental information system afterwards. As a consequence, the decision-maker is only able to conduct fuzzy controlling with taking the forecasts of the investment database as rough orientation. In this context, it is interesting to notice that two out of three case studies are on track to meet the given environmental goals. On the one hand, a reason for that might be found in the coincidentally right decisions made by the executive management, who is only able to control environmental impacts on basis of their gut feelings so far. On the other hand, the focus on increasing production efficiency also automatically reduces resource and emission flows and thus also helps to support strategic environmental goals. Additional explanations involve environmental goals being too moderate or a huge amount of organisational measures which also support the achievement of environmental goals as well.

Besides the criticism of the lacking standardisation within the investment database, the existence of such a database is important regarding various aspects. Without this database, it would be impossible to provide any forecast and therefore the decision-maker would be unable to invest towards the achievement of strategic environmental goals. Another important aspect is the ability to share knowledge and ideas, especially in multi-national companies as well as decentrally-organised companies. Furthermore, the opportunity would be foregone to generate investment ideas from technical planners and operating personnel, who are internal experts regarding production process optimisations.

In conclusion, the standardised documentation in form of a group standard for the investment database needs to be implemented. Another improvement would be the integration of the investment database within the shared environmental information system to ensure that forecasted resource and emission flows are mirrored in the actual environmental performance later on. In addition, the scope and depth of measuring points need to be increased in order to perform validity checks based on measured data.

6. Validity and reliability of results

This chapter aims to assess the validity and reliability of the results. In context of the initial requirements assessment, validity and reliability are defined as key requirements regarding the development and application of the integrated investing method. While validity assesses whether the method serves its intended aim, reliability ensures that the repetition of the research process leads to similar findings even if the research process is executed by a different researcher.

Construct validity

With regard to the validity of the findings, one sub-type represented by construct validity intends to avoid subjectivity within the research process. This subjectivity by the researcher, for instance, might have an influence on the data collection. Therefore, counter measures suggest drawing on multiple sources of evidence which is referred as '*triangulation of data*' (Stake, 1995).

In the context of this thesis, this triangulation of data is taken into consideration via drawing on several documentary data and via e-mails which were sent in case data gaps had to be filled. For instance, in single investment case studies, several documentary data sources comprise the specifications sheet of Volkswagen, the offers of the supplying companies as well as the calculations of the technical planning and management accounting departments. Furthermore, e-mails were sent to close gaps in data collection. Finally, a draft case study report is sent to the cooperating employees of the planning or management accounting department to verify the correct reporting and to avoid subjective judgements as well as calculation errors.

Furthermore, the case study research design includes a section listing the underlying propositions influencing the research. This list of underlying propositions contains a brief review of the concepts and theories on which the case study research design is based and which have an influence on the researcher regarding the data collection and data analysis. The cross-case synthesis does not reveal any contradiction of findings with the underlying propositions which undermines the construct validity of this thesis.

Internal validity

The validity sub-type regarding internal validity is concerned with the assessment whether the findings are in coherence with the evidence and whether the observed causal relationships are free from methodical error (Yin, 2014). This sub-type is difficult to assess for non-exploratory research. However, an indicator for the internal validity of the findings can be provided in context of the cross-case synthesis of single-investments. While it is previously expected that the context has a significant influence on the application of the integrated investing method, the type of the investment showed a significant impact instead. In case, the research would not be free from methodological error and bias, this finding might have been in coherence with previous expectations. Moreover, the identified pattern between greenfield and brownfield cases and the implications for the application of the integrated investing method can be found within the context of the cross case synthesis.

External validity

The validity sub-type addressing external validity assesses in how far the findings in the context of this thesis can be generalised to contexts outside the dissertation. While the integrated investing method is developed according to already existing approaches which are designed for a generic application, the description along the conventional investment process in companies ensures a systematic generalisability.

Furthermore, the integrated investing method is applied in different contexts throughout the automotive production. The subsequent cross-case synthesis technique aims to analyse the cases via comparison and intends to generate detailed findings from this method application.

In general, the four single investment case studies reveal that a successful application of the integrated investing method is possible for single investments. Most of the problems reveal differences between theory and business practice. The cross-case synthesis additionally expose that not every suggested step needs to be conducted in order to successfully apply the integrated investing method in practice. The case studies show that the integrated investing method also works without a determination of quantified target or without financial and environmental budgets for the mapping of investment objects. However, the low amount of competing investment objects provides limitations of the integrated investing method. Hence, it is desired to research at least three investment objects per investment case for a comprehensive investment decision.

The cross case synthesis of the three investment program case studies reveals that it is possible to manage and control environmental goals based on the integrated investing method. Important prerequisites are on the one hand the existence of quantified environmental goals and a compensation system that rewards the achievement of these goals on the other hand. Nevertheless, an important part is a comprehensive database listing the single investments and their status of implementation. This database requires constant maintenance to keep all information up-to-date. An additional important part is comprehensive environmental information system providing the basis of the environmental performance measurement. In this context, appendix 4 provides a checklist for applying the integrated investing method, while appendix 3 provides detailed insights in the environmental impact assessment, based on the ESM.

Reliability

The main question underlying the reliability of the research assesses whether findings are replicable in case the same research is conducted by different individuals. On the one hand, this involves sufficient transparency and comprehensibility of the research process but also a standardised and well-documented research procedure.

While this dissertation intends to answer the main research question on the one hand, it also aims to verify a sufficient degree of scientific procedure. Hence, applied methodologies are critically discussed and research procedures are documented in detail. One example in this context is the evaluation of analysed approaches via the requirements assessment. While the choice and definition of requirements are transparently discussed and documented, the corresponding evaluation parameters are determined with the aim to design a reliable evaluation process.

Another example in this context is the application of case study protocols according to the same template. In addition, the underlying calculations for the single investment cases but also for the investment program cases all shared the same Excel spreadsheet templates. Moreover, a case study database is created through the research process containing all collected and analysed data of all conducted cases. This database even comprises cases which are not selected to be part of the method application in the context of this dissertation.

In addition, appendix 3 provides a detailed description of the underlying calculations of the environmental impact assessment of a case study, intending to better comprehend the results.

Finally, all these structuring, standardising and documenting efforts aim to avoid bias and minimise the likelihood of errors during the research process but also intend to increase the reliability of the results of this dissertation.

7. Conclusions and recommendations

Conclusions

This chapter aims to verify whether the originally formulated problem situation is solved and the intended research objective is achieved. Therefore, this chapter reviews whether the main research question and the corresponding sub-research questions are answered throughout the content of this dissertation.

The introduction recognises two common cross-sectional systems within a company with the environmental management system on the one hand and the management accounting system on the other hand. The overlapping part of both systems is referred to as the environmental management accounting system. It is stated that research in this field is still young and corresponding methods are currently under development.

The subsequent problem situation analyses the problems related with environmental management accounting systems in detail. On the one hand, there is uncertainty concerning the achievement of environmental goals which originating on the one hand from the qualitative formulation of environmental goals and on the other hand on the lacking systematic integration of environmental goals in management accounting processes. Thus, the systematic integration of environmental management information in investment processes is identified as research gap.

As a consequence, the research objective aims to develop a new method that is able to systematically integrate environmental impacts in investment decisions within companies and to verify its practical applicability. Therefore, the main research question is formulated as follows:

How to integrate financial and environmental data in investment processes to achieve financial and environmental strategic goals of companies?

The subsequent methodology discloses the planned structure of the research procedure and activities in the context of this thesis. In addition, the methodology breaks down the main research question into four sub-research questions which are intended to be answered by the specific chapters of this dissertation. Once, the sub-research questions are answered, it is able to answer the main research question within this chapter. The sub-research questions provided in the methodology chapter are formulated as follows:

<u>*Sub-research question 1:*</u>
Which requirements does the integrated investing method need to meet in order to ensure a sufficient degree of scientific quality?

<u>*Sub-research question 2:*</u>
Which requirements does the integrated investing method need to meet in order to ensure its practical applicability?

Sub-research question 3:
How well do additional methods from environmental management and management accounting systems meet the requirements to qualify as a basis for the development of the integrated method?

Sub-research question 4:
Does the method application verify the practical applicability of the developed method and the ability to manage and control strategic environmental goals of an existing company?

With regard to the first and second research question, the requirements ensuring a sufficient degree of scientific quality on the one hand and practical applicability on the other hand are determined within the deficit analysis as well as in the first part of the subsequent method development chapter. Therefore, there are four requirements aiming to ensure a sufficient degree of scientific quality and three requirements ensuring practical applicability (see Table 89).

Table 89: Summary of requirements as a basis for the method screening and evaluation

Scientific quality	Practical applicability
Environmental inventory	Comprehensibility
Environmental impact assessment	Transparency
Validity	Monetary evaluation
Reliability	

Source: Own representation

This set of requirements is defined in detail and corresponding evaluation parameters are determined within the first subchapters of the method development chapter. Afterwards, additional methods from environmental management and management accounting systems are screened and evaluated based on these seven requirements, in order to determine a basis for the development of the integrated investing method. This method screening and evaluation process comprises the second part of the method development chapter and its result provides the answer to the third sub-research question.

The result reveals that there is no single method which meets all seven requirements. In addition, there are three approaches which show sufficient potential for further method development, comprising flow-based cost accounting, environmental indicators as well as the VDI-guideline 3800. Therefore, an additional sub-research question is inserted at this point which is formulated as follows:

Sub-research question 3a:
How to combine these three methods to develop an integrated investing method which is able to meet all seven requirements ensuring sufficient scientific quality and practical applicability?

As a consequence, the third part of the method development chapter (method derivation) assesses the strengths and weaknesses of the remaining three methods with the intention to provide an answer to the above-mentioned sub-research question 3a. The result can be retrieved in the fourth chapter of this dissertation comprising a detailed description of the developed integrated investing method which is structured along the phases of the conventional investment process within companies.

After this theoretic development of the integrated investing method, the fourth sub-research question intends to verify the practical applicability of the integrated method and its ability to manage and control environmental goals of a company. This sub-research question is answered within the fifth chapter of this dissertation comprising the method application within seven independent case studies. The concluding cross-case synthesis reveals that a practical application of the integrated investing method is generally possible in different contexts. The identified problems mainly originate from a lack of a sufficient amount of researched investment alternatives.

In addition, the integrated investing method can still be successfully applied even if not all suggested steps are conducted. Furthermore, three case studies verify the ability to manage and control environmental goals. However, it is necessary to provide a database containing environmental and financial data regarding planned and realised investments as well as an up-to-date environmental information system.

Finally, the main research question can be answered. With the help of the integrated investing method, as described in the fourth chapter of this dissertation, it is able to systematically integrate financial and environmental data in investment processes in order to manage and control strategic environmental and financial goals of a company. The integrated investing method is able to meet requirements regarding a sufficient degree of scientific quality on the one hand and practical applicability on the other hand. In addition, the integrated investing method is successfully applied in case studies and has verified its ability to manage and control environmental goals of a company on various management levels.

Recommendations

The recommendations regarding future research are mainly structured along the identified limitations in context of the summaries and discussions of this thesis. One major part addresses the limitations with regard to the dependency of the integrated investing method on the ESM.

The ESM intends to identify the level of ecological scarcity for an environmental aspect in a specific country. This ecological scarcity is represented by the relation of critical flows to actual flows. Nevertheless, this relation is constantly changing due to new threshold values or legal requirements as well as changes in actual resource and emission flows of a country. Therefore, the eco-factors within the ESM need to be updated regularly. In order to provide a sufficient degree of objectivity, this task needs to be executed by federal institutions or independent universities.

Furthermore, future research should concentrate on expanding the limited amount of available eco-factors so far. While most of the relevant environmental aspects within the automotive manufacturing process are covered by eco-factors which are currently available, the application of the integrated investing method in other contexts outside the automotive industry might be limited due to missing eco-factors.

An additional point in this context is the limited availability of country-specific eco-factors outside Germany. While the ESM was originally developed in Switzerland, there is only a limited amount of available country-specific eco-factors for countries outside Germany and Switzerland. Hence, future research should focus on developing additional country-specific eco-factors for countries outside Germany and Switzerland.

Especially for multi-national corporations, it is necessary to conduct comparisons of production sites, or corresponding processes, which are located in different countries. Once, additional eco-factors are available for various countries, this opportunity is theoretically given. Nevertheless, one eco-point of one country cannot directly compared to one eco-point from another country, due to the different underlying eco-factors. Therefore, future research has to develop a transfer mechanism, possibly in analogy to currency conversion rates, to be able to finally conduct cross-country comparisons of environmental impacts.

Another part of recommendations for future research addresses the systematic and comprehensive application of the integrated investing method within a company. So far, the integrated investing method is applied in single investments and with the help of generic databases comprising investment programs and corporate environmental performance measurement. However, a systematic integration has not been established. The Volkswagen Group already provides a good basis for this research. The aim of this future research is to collect evidence and experience regarding the systematic and comprehensive application of the integrated investing method in all investment processes and the environmental management control system. This experience might help to develop the integrated investing method further so that it can be established as accepted standard in business in future.

Besides this long-term application, the application of the integrated investing method in other contexts is of interest for future research. Hence, the application within an automotive OEM outside the Volkswagen Group might gain additional insights for further development of the integrated investing method in future. In addition, the application outside the automotive industry would comprise the insight in how far the limited amount of eco-factors also limits the application of the integrated investing method. Finally, the application within small and medium-sized companies as well as contexts outside the private sector, namely within the public sector, is of interest of recommended future research. In this context, appendix 4 provides a checklist for applying the integrated investing method in companies and appendix 3 comprises and exemplary calculation of the environmental impact with the intention to increase the reliability of the integrated investing method.

Finally, as a consequence of a systematic integration within a company, the influence and impact on the conventional investment process, especially on the investment decision is an interesting field of future research. Hence, the question in how far the integrated investing method has changed the outcome of investment decisions is recommended for future research. This question can also be addressed by recognising different corporate cultural backgrounds throughout different companies as well as cultural backgrounds of different countries.

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Appendix 1 – The Ecological Scarcity Method

The Ecological Scarcity Method (ESM) is based on a concept of Müller-Wenk (1978), which intends to establish an ecologically-based internal accounting system. This accounting system provides ecological ledgers which record resource and emission flows in order to assess the environmental impact of a company and its products. Within this concept, the environmental impact assessment was conducted with so-called equivalent factors. (ibid.) These equivalent factors were developed further by Ahbe *et al.* (1990) in Switzerland to conduct an environmental impact assessment of packaging materials amongst others.

Today, the ESM is used for the impact assessment within Life-Cycle Assessments (LCA) but also other studies conducting an environmental impact assessment. The main object within the ESM is a set of so-called country-specific '*eco-factors*', which are multiplied with their corresponding resource and emission flows in order to determine the corresponding environmental impact. In addition, eco-factors enable transferring the various units of measurement from the resource and emission flows to one common unit of measurement - the '*eco-points*' indicator. As a consequence, the environmental impacts of the resource and emission flows under consideration can be aggregated in one amount of eco-points, which in turn determines the severity of the total environmental impact. Thus, the higher the amount of aggregated eco-points, the higher is the environmental impact. (Frischknecht and Büsser Knöpfel, 2013)

The calculation of the eco-factor

The eco-factor represents the main object of the ESM. Strictly seen, the ESM only describes the calculation of eco-factors but not the application of eco-factors in environmental impact assessment studies. Nevertheless, eco-factors intend to imply the environmental impact assessment by representing the ecological scarcity of a given set of resource and emission flows in a country. This ecological scarcity is represented by a weighting factor that relates actual flows to critical flows, which describe the desired maximum value of resource consumption or emission within this country. Hence, the ESM is classified as so-called '*distance-to-target*'-method. (Frischknecht and Büsser Knöpfel, 2013)

With regard to the calculation of the eco-factors, the underlying formula consists out of four terms performing a characterisation, normalisation, weighting and a constant to ensure a better comprehensibility of high figures. The formula for calculating an eco-factor is expressed in literature as follows:

Figure 83: Formula for calculating an eco-factor

$$Eco-factor = \underbrace{K}_{\substack{\text{Characterization}\\ \text{(optional)}}} \cdot \underbrace{\frac{1 \cdot \text{UBP}}{F_n}}_{\text{Normalization}} \cdot \underbrace{\left(\frac{F}{F_k}\right)^2}_{\text{Weighting}} \cdot \underbrace{c}_{\text{constant}} \qquad (4)$$

with:

K	= *Characterization factor of a pollutant or a resource*
Flow	= *Load of a pollutant, quantity of a resource consumed or level of a characterized environmental pressure*
F_n	= *Normalization flow: Current annual flow with Switzerland as the system boundary*
F	= *Current flow: Current annual flow in the reference area*
F_k	= *Critical flow: Critical annual flow in the reference area*
c	= *Constant* ($10^{12}/a$)
UBP	= *Eco-point: the unit of the assessed result*

Source: Frischknecht and Büsser Knöpfel, 2013:49

The characterisation term (K) at the beginning of the formula can be used in case resources or emissions can be assigned to the same environmental impact. This is the case, for instance, for gaseous emissions into the air, for which there is a global consensus regarding their global warming potential. Besides a global scientific consensus on this characterisation factor, another precondition is the existence of political targets from which the characterisation factors can be derived. (Frischknecht and Büsser Knöpfel, 2013)

The normalisation term, as the second term in the formula above, provides the opportunity of assessing the ecological scarcity within one region instead of a whole country. Regionalised eco-factors are especially helpful for big countries in which scarcity situations vary widely, for instance due to existence of hyetal regions and arid regions in one and the same country. In case of regionalised eco-factors, the normalisation flow (F_n) comprises the flow for the whole country, while current flow (F) and the critical flow (F_k) within the weighting term comprise regional values. (ibid.)

The weighting term, as the third term in the formula above, depicts the actual ecological scarcity situation. This term contains the total flows of a resource or an emission within one country in a specific year (F) and the critical flow which is either the total threshold value which should maximal be consumed or emitted within the same country in a specific year (F_k). This critical flow is ideally derived from environmental legislation of the country. (ibid.) The intention behind squaring the relation of F to F_k is to assign more weight to the critical flow. Hence, "*the higher the current pollution already is, the more strongly every additional emission is weighted*" (ibid:50).

The final term within the formula is represented by the constant (c) and serves on the one hand as eliminator for the temporal expression remaining from the weighting term (e.g. tonnes CO_2/year) and on the other hand to transfer values of high magnitude to easy-to-comprehend values. (ibid.)

Example calculation of an eco-factor

With regard to the eco-factor for emissions of CO_2-equivalents in Germany, Ahbe *et al.* (2014) illustrates a transparent exemplary calculation. On basis of a report of the German federal environment agency, the authors identified the current flow (F) in the year 2011 of 916,769 kilotons CO_2-equivalents in Germany. The German legislation aims to reduce the emission of CO_2-equivalents by 80 percent till 2050 based on emissions measured in the year 1990. Hence, the critical flow (F_k) is determined with 246,486 kilotons CO_2-equivalents. (Ahbe *et al.*, 2014)

Hence, the eco-factor for CO_2-equivalents in Germany can be calculated, which is depicted in the following figure:

Figure 84: Exemplary calculation of the eco-factor for CO_2-equivalents in Germany

$$\ddot{O}F_{CO2-eq} = 1 \cdot \frac{UBP}{916.769 * \frac{10^9 g}{a}} \cdot \left(\frac{916.769 * \frac{10^9 g}{a}}{246.486 * \frac{10^9 g}{a}} \right)^2 \cdot \frac{10^{12}}{a} = 0{,}015 \, \frac{UBP}{g}$$

Source: Ahbe et al., 2014:29

As a consequence, the ecological scarcity regarding the emissions of CO_2-equivalents in the air in Germany is evaluated with an eco-factor of 0.015 eco-points per gram CO_2-equivalents. In a subsequent step, the emission flow of CO_2-equivalents, for instance, caused by a plant in Germany can be multiplied with the eco-factor in order to determine the environmental impact as expressed in an amount of eco-points. Likewise, other resource and emission flows can be multiplied with their corresponding eco-factors in order to determine the associated environmental impacts. Finally, the total environmental impact can be calculated by adding up the various amounts of eco-points, as expressed in the figure below:

Figure 85: Exemplary calculation of the total environmental impact of a fictitious plant

annual environmental inventory				eco-factors*		=	eco-points
Energy consumption (electricity / heat)	304,987	MWh	X	0.506	EP / MJ-eq.**	=	556 EP*10⁶
CO_2 emissions	83,062	t	X	0.015	EP / g	=	1,246 EP*10⁶
Fresh water consumption	558,420	m³	X	22.630	EP / m³	=	13 EP*10⁶
Waste production	5,015	t	X	0.007	EP / g	=	35 EP*10⁶
VOC emissions	252	t	X	1.475	EP / g	=	372 EP*10⁶
						Σ	**2,222 EP*10⁶**

* eco-factors for Germany based on Ahbe *et al.*, 2014

** assumption that total energy consumption is generated from non-renewable energy resources, 1 MWh = 3600 MJ-eq.

Source: Own illustration

Availability of eco-factors

Generally, eco-factors are publically available. However, they are limited with regard to their scope and the countries on which the ESM has been applied. Since the ESM was originally developed in Switzerland in the 1990s, the set of Swiss eco-factors was constantly updated and expanded

(Frischknecht and Büsser Knöpfel, 2013). The latest update which was published by the Swiss Federal Office for the Environment (FOEN) in 2013 represents the broadest set of available eco-factors (Frischknecht and Büsser Knöpfel, 2013).

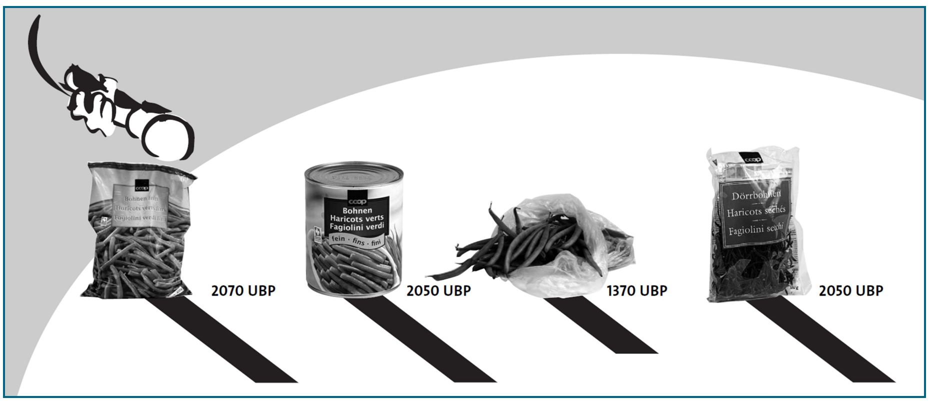
In their latest publication, Frischknecht and Büsser Knöpfel (2013) claim that there are eco-factors available for the countries Belgium, Sweden, Norway, the Netherlands, Jordan and Japan. Nevertheless, these publications represent single case studies applying the ESM on country-specific environments. An important point when applying the ESM is the validation of the underlying data (especially regarding current and critical flows) by official institutions such as the environmental agency or environmental ministry of a country to ensure the neutrality of eco-factors (Ahbe *et al.*, 2014).

In this context, the Volkswagen Group has launched an initiative that applies the ESM on Germany. The underlying data were researched by the Technische Universität Darmstadt and validated by the German federal environment agency. Finally, the results were made publically available by Ahbe *et al.* (2014). Another project of this Volkswagen Group initiative intends to develop eco-factors for the 28 member countries of the European Union (Damme, 2014). The underlying data were validated by the European Environment Agency. Unfortunately, the results were not yet publically available at the time this dissertation was handed in. Nevertheless, the list of countries on which the ESM has been applied and for which eco-factors are available is expected to constantly grow in future.

Application of the eco-factors

Due to the comparably long history of available eco-factors, it is not surprising that the ESM has gained increased popularity in Switzerland. Hence, the concept of ecological scarcity is taught in Swiss schools and the eco-factors are used to explain the environmental impacts of personal consumption (BAFU, 2008). Within one school lesson, for instance, pupils are taught the difference in environmental impact of differently cooked and packaged beans. The environmental impact is expressed in the total amount of eco-points while visualised in form of ‘ecological shadows’, as expressed in the following figure:

Figure 86: Example for the application of the ESM in schools in Switzerland

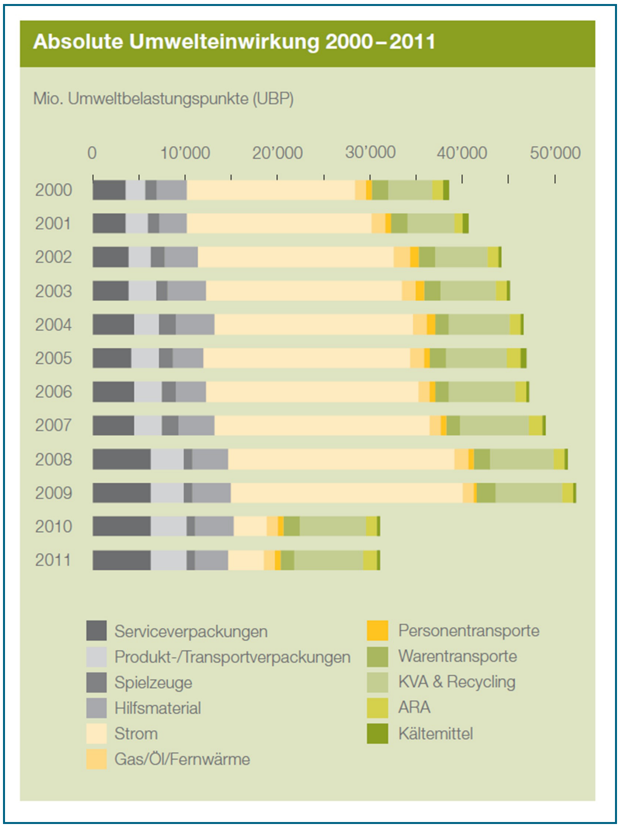


Source: BAFU, 2008:6

Besides the application in schools, the Swiss government has implemented LCA studies with impact assessments based on the ESM in parts of its legislation. For instance, the Swiss Biofuels Life Cycle Assessmeent Ordinance requires a demonstration of positive environmental impacts of biofuels in comparison to conventional fuels (Frischknecht and Büsser Knöpfel, 2013).

Additional cases of application of the ESM in Switzerland deal with the external disclosure of companies in form of environmental and sustainability reports. For instance, the fast food chain Mc Donald's expressed the environmental impact of its operations in Switzerland within its Corporate Sustainability Report in 2012 (see Figure 87) (McDonald's Suisse Restaurants, 2012). Further Swiss companies as the producer of sanitar parts, the Geberit AG or advertising company, the APG|SGA SA use the eco-points indicator to express the environmental impact of their operations (Geberit AG, 2014; APG|SGA, 2012).

Figure 87: Exemplary illustration of application of the ESM in external reports of companies



Source: Mc Donald's Suisse Restaurants, 2012:26

Due to the absence of German eco-factors till the year 2014, the application is limited to the use of the ESM in context of environmental management systems in Germany. In this context, the Volkswagen Group applied eco-factors to measure the environmental impact of its production plants with the intention to derive appropriate environmental goals for its environmental management system (Gernuks, 2005). As a consequence, the Volkswagen Group includes the eco-points indicator in its disclosure in form of its environmental declarations (Volkswagen, 2015b).

Regarding the application of the eco-factors in context of this thesis, the author referred to the latest publication of German eco-factors, published by Ahbe *et al.* (2014), which are summarised in the figure below:

Figure 88: Summary of German eco-factors as applied in context of this thesis:

Umwelteinwirkung	Aktueller Fluss	Kritischer Fluss	Ökofaktor: UBP/Einheit	
Luftbelastung:				
CO2-eq [kt/a]	916.769	246.486	0,015	/g
NMVOC [kt/a]	1.006	826,0	1,475	/g
NOx als NO2 [kt/a]	1.288	652,0	3,03	/g
SO2 [kt/a]	445,0	324,0	4,239	/g
Feinstaub PM2,5 [kt/a]	111,0	79,0	17,79	/g
NH3 [kt/a]	563,0	426,0	3,102	/g
Belastung Oberflächengewässer				
Stickstoff [t/a]	564.800	515.550	2,125	/g
Phosphor [t/a]	22.200	8.822	285,2	/g
Nickel [t/a]	476,8	225,0	9.418	/g
Zink [t/a]	2.755	1.765	885	/g
CSB [t/a]	490.800	264.666	7,01	/g
Blei [t/a]	263,0	65,75	60.846	/g
Cadmium [t/a]	9,23	2,31	1.729.728	/g
Kupfer [t/a]	461,2	352,9	3.703	/g
EPA-PAK16 [t/a]	19,16	4,41	985.186	/g
Ressourcen				
Süßwasserverbrauch [Mio m3/a]	32.000	37.600	22,63	/m3
Energieeffizienz/-Knappheit:				
Primärenergieverbrauch PEV [PJ/a]	13.599	7.140	-	
Verbrauch erneuerbarer Energie [PJ/a]	1.463	2.245	0,349	/MJeq
Verbr. nicht erneuerb. Prim.Energie [PJ/a]	12.136	4.895	0,506	/MJeq
Abfall				
Abfallaufkommen, ungefährlich [Mt/a]	136,82	136,82	0,0073	/g
Abfallaufkommen, gefährlich [Mt/a]	15,73	15,73	0,0636	/g

Source: Ahbe et al., 2014:10

Appendix 2 – Pilot case study

This pilot case represents a comparison of energy supply concepts for electricity and technical heat for a testing site. The selection criteria of the pilot case base on two reasons. First, the scope and quality of data provided sufficient basis for testing the integrated investing method. Second, the management and the employees of the service engineering department showed great interest in the development and use of the integrated investing method. Hence, they were open-minded but also critical partner that provided extensive feedback on the integrated investing method.

Initial situation

The context of the pilot case is represented by an investment to update an old heating concept of a testing site within the research and development business unit. The concept currently in place involves the generation of heat via an old oil heating. Since the operating costs of the old oil heating increase as well as its maintenance effort, an investment in alternatives is necessary. In the context of this investment need, the management discussed the alternative of investing in a combined heat and power station (CHP). In this case, heat would be generated but also electricity. This electricity could be consumed on the testing site or fed into the electricity grid, depending what is economically most feasible. As a consequence, the following three alternatives are discussed:

- acquisition of two gas-fired boilers to generate heat only
- acquisition of a CHP fired with natural gas from which 40 percent electricity is fed into the grid
- acquisition of a CHP fired with biogas from which 100 percent electricity is fed into the grid

The description of the initial situation already indicates the reason for the investment which is in this case an old oil heating, generating too high operation expenditure and maintenance efforts. In addition, the initial situation reveals another issue concerning the delimitation of the case. Since only one alternative represents a direct replacement of the old oil heating with two gas-fired boilers, it is questionable whether the asset which is subject to be replaced should function as framing element. Hence, the scope of the investment needs to be broadened from the consideration of the oil heating to the combined heat and electricity supply concept of the testing site.

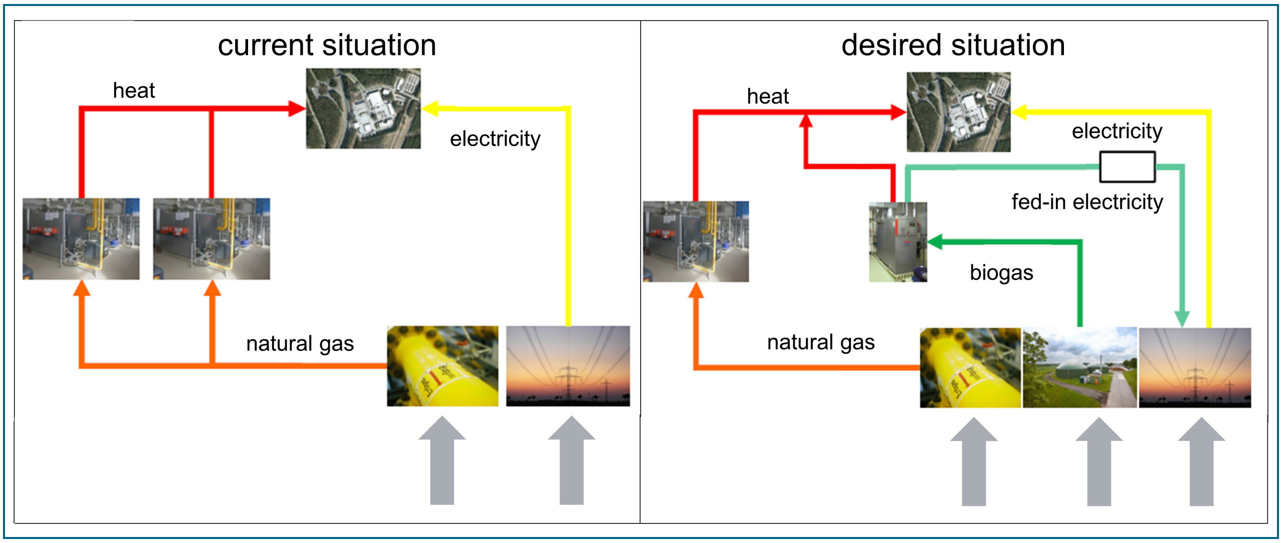
As a consequence, it is suggested to provide information about the context of the case as well as a determination of the investment within this case study. This determination of the investment can be structured along the definition of investments in the context of this dissertation which is provided in chapter two (i.e. state of current academic knowledge).

Furthermore, it is helpful to structure the case study along the conventional investment process within companies which is provided in chapter two as well. This structure ensures that the information in context of the investment cases are presented and discussed along a logical and chronological structure. In the context of this case study, the initial situation already implies information of two phases which is the problem situation as well as the search for investment objects. Structuring the case study report along the conventional investment process also provides the advantage that all relevant information can be presented in detail in the corresponding phase.

For instance, the competing investment objects can be visualised when discussing them in context of the second investment phase (i.e. search for investment alternatives). This visualisation might comprise an input-output scheme or a flow model.

Hence, the competing investment objects can be visualised as follows:

Figure 89: Visualisation of resource flows of competing alternatives within a rough flow model



Source: Own illustration according to Volkswagen, 2013a

Besides the visualisation of the investment alternatives, the amounts of resource and emission flows as well as their corresponding eco-points per investment object should be compared in a table to provide an overview and understanding of the discussed investment alternatives:

Table 90: Comparison of resource flows and corresponding eco-points of three alternatives

Consumption	Two gas-fired boilers	Natural gas CHP with 40% fed-in electricity	Biogas CHP with 100% fed-in electricity
Electricity consumption (in MWh/a)	35,567.40	27,612.75	35,567.40
Gas consumption (in MWh/a)	24,226.10	42,938.10	39,366.60
Eco-points from electricity consumption	1,281.91	995.21	1,281.91
Eco-points from gas consumption	327.41	580.29	389.04
Sum of eco-points	**1,609.31**	**1,575.50**	**1,670.95**

Source: Volkswagen, 2013a [data adjusted according to secret factor]

Due to confidentiality standards within the Volkswagen Group, the values in the table above were adjusted according to a secret factor. This enables to keep the proportions and the underlying interpretations similar while not revealing confidential information.

Table 90 shows the insight that the second alternative intending to provide heat and electricity with a CHP station while feeding in 40 percent of the generated electricity is the most environmentally friendly alternative, showing the lowest amount of eco-points. In this case, the reader might face uncertainty regarding the origin of the results. Hence, it would make sense to explain the difference between the three alternatives and the implications for the calculation of the corresponding eco-points.

This explanation should comprise the technology behind a CHP station. Hence, the reader would gain the insight that a CHP station generally consumes more gas than the two gas-boilers since the CHP station also generates electricity. As a consequence of this generated electricity, there is less electricity consumed originating from the grid.

In order to represent a combined environmental and economic investment appraisal, the integrated investing method suggests composing a set of financial, environmental and eco-efficiency indicators. The following table summarises the adjusted values of the three alternatives according to the suggestions of the integrated investing method:

Table 91: Overview of suggested indicators by the integrated investing method for the three alternatives

Indicators	Two gas-fired boilers	Natural gas CHP with 40 % fed-in electricity	Biogas CHP with 100 % fed-in electricity
Capital expenditure	2,818,890.80	6,535,893.32	6,501,023.32
Operating expenditure	3,907,506.41	3,884,397.34	3,860,411.08
Eco-points	1,609.31	1,575.50	1,670.95
Reduced eco-points	265.05	298.86	203.41
Investment eco-efficiency	10,635.51	21,869.47	31,959.91
Operating eco-efficiency	14,742.80	12,997.42	18,978.30
Operating eco-efficiency relation	- 0.27	- 0.30	- 0.25

Source: Own calculation according to Volkswagen, 2013a [data adjusted according to secret factor]

Again, the values in the table above are adjusted according to a secret factor in order to meet the confidentiality standards of the Volkswagen Group. The resulting indicators in Table 91 provide a mixed conclusion. While the alternative comprising the investment into two gas-fired boilers shows the best advantageousness regarding the investment eco-efficiency, the second alternative listed in the middle column represents the best operating eco-efficiency. In this case, the integrated investing method suggests conducting the utility value analysis in which the environmental, financial and eco-efficiency performance is ranked and summed up to identify the best investment object.

However, the ROI, NPV and PBP indicators are missing in the context of this case. In addition, the operating eco-efficiency relation is not ranked due to the missing investment eco-efficiency relation indicator. As a consequence operating efficiency would be over-weighted. Hence, the weightings in the context of this pilot case study are represented as follows:

Table 92: Weighting factors in the context of the pilot case study

Classification	Name	Weighting factor
Financial indicators	Capital expenditure (capex)	0.5
	Operating expenditure (opex)	0.5
Environmental indicators	Environmental impact	1
Eco-efficiency indicators	Investments eco-efficiency	0.5
	Operating eco-efficiency	0.5

Source: Own representation

Finally, the total utility values are represented as follows:

Table 93: Total utility value of the three investment objects of the pilot case study

Indicator	Two gas-fired boilers	Natural gas CHP with 40% fed-in electricity	Biogas CHP with 100% fed-in electricity
Capital expenditure	#1 (0.5)	#3 (1.5)	#2 (1.0)
Operating expenditure	#3 (1.5)	#2 (1.0)	#1 (0.5)
Environmental impact	#2 (2.0)	#1 (1.0)	#3 (3.0)
Investment eco-efficiency	#1 (0.5)	#2 (1.0)	#3 (1.5)
Operating eco-efficiency	#2 (1.0)	#1 (0.5)	#3 (1.5)
Total utility value	**#1 (5.5)**	**#2 (5.0)**	**#3 (7.5)**

Source: Own calculation

As a consequence, the rationale decision-maker would decide to invest in the alternative intending to install a natural-gas-fired CHP with 40 percent fed-in electricity into the grid since this alternative represents the best, respectively the lowest total utility value.

One of the limitations of this pilot case is that it does not comprise the investment realisation. In addition, it is not known how the investment decision turned out in practice. Nevertheless, the pilot case intended to test the case study research design and to describe implications for the case study protocol.

While a pilot study has been conducted in advance to the single investment case studies, no additional pilot study was conducted before investment program case studies.

Appendix 3 – Exemplary environmental impact assessment

This appendix contains an exemplary calculation of the environmental impact assessment of a single investment case study in order to provide detailed insights on the underlying calculations. The case study regarding the retrofit of a transfer press represents the basis for this appendix. Therefore, please refer to subchapter 5.3.2. for additional details, for instance, concerning the problem situation or other phases of the investment process.

The resource and emission flows, which could be quantified and measured in this case study, are the following:

- electricity consumption
- compressed air (6 bar)
- compressed air (12 bar)

Hence, the resource flows for the transfer press before the retrofit measure was executed (i.e. current situation) can be retrieved in the following table:

Table 94: Overview of resource flows of the transfer press before retrofit

Resource flow	Consumption	Unit
Electricity	8,057.163	MWh/a
Compressed air (6 bar)	10,531,655	Nm^3/a
Compressed air (12 bar)	96,970	Nm^3/a

Source: Own calculations on the basis of Volkswagen, 2014c [data adjusted according to secret factor]

Due to confidentiality reasons, these values were adapted according to a secret factor which is only known to the author of this dissertation.

In order to calculate the environmental impact of the current situation via the ESM, the resource flows need to be multiplied with their corresponding eco-factors. Since the investment object is located in Germany, the eco-factors as published by Ahbe *et al.* (2014), need to be consulted. While there is no specific eco-factor for the consumption of compressed air, the eco-factors for electricity consumption are illustrated in Table 95. The environmental impact resulting from the consumption of compressed air can be calculated via the electric energy, which is necessary to generate the amount of consumed compressed air. This calculation is demonstrated after the environmental impact of electricity consumption is explained.

Table 95: German eco-factors regarding energy efficiency/-scarcity

Category	Eco-factor	Unit
Energy efficiency/scarcity		
Consumption of renewable energy	0.349	eco-points per MJ-eq
Consumption of non-renewable primary energy	0.506	eco-points per MJ-eq

Source: Based on Ahbe et al., 2014

The ESM suggests multiplying the resource flow with the corresponding eco-factor, in order to calculate the amount of eco-points, which represents the environmental impact. However, the energy consumption, provided by the technical planning department, is expressed in final energy, while the eco-factor for non-renewable energy is expressed in primary energy. While there is a need for implementing some kind of adaptation on the one hand, it is also necessary to research the proportions of renewable energy and non-renewable energy within the provided amount of final energy (see Table 94) on the other hand.

As a consequence, the following step comprises researching the energy sources and their proportions used to generate the final energy, which is consumed by the transfer press. In this case study, the Volkswagen Group owns an energy producing business unit which operates own power plants. Besides operating own power plants, this business unit sells and buys electricity on the market. Hence, the energy sources and their corresponding proportions are expressed in the following table:

Table 96: Energy source mix in context of this case study

Energy source	Proportion
Nuclear energy	1.90 %
Hard coal	75.00 %
Natural gas	14.60 %
Petroleum products	1.00 %
Renewable energies	7.50 %
Sum	**100.00 %**

Source: According to Wellge, 2015

Besides the mix of energy sources, the transfer from final energy to primary energy needs to be conducted. A primary energy factor briefly accounts for the primary energy (or cumulated energy) necessary to provide the basis of final energy consumption (Molenbroek *et al.*, 2011). In context of this thesis, it is only necessary to research primary energy factors for non-renewable energy sources since the eco-factor for renewable energy is already expressed in eco-points per MJ of final energy consumption. The publication of Itten and Frischknecht (2014) provides a set of primary energy factors that are explicitly recommended for the use in context of the ESM.

Table 97: Primary energy factors used in context of this thesis

Energy source	Primary energy factor	Unit
Nuclear energy	4.22	MJ-eq/MJ
Hard coal	3.94	MJ-eq/MJ
Natural gas	2.22	MJ-eq/MJ
Petroleum products	3.73	MJ-eq/MJ

Source: According to Itten and Frischknecht, 2014

As a consequence, the environmental impact of the primary energy supply, which is caused by the energy demand of the transfer press, can be calculated. Since the primary energy factor is expressed in MJ-eq per MJ, the unit of the electricity consumption of the transfer press needs to be adjusted. This adjustment can be conducted by multiplying the 8,075.163 MWh with the factor 3,600 since this represents the conversion rate from MWh to MJ (Posselt, 2015). The resulting 29,005,786 MJ represent the input for the calculation of the environmental impact caused by the primary energy supply. This calculation multiplies the input (29,005,786 MJ) with the proportions of the energy source mix and the corresponding primary energy sources before multiplying with the corresponding eco-factors. Finally the single eco-points can be aggregated to represent the environmental impact cause by the primary energy supply (see table below).

Table 98: Calculation of the environmental impact caused by the primary energy supply

Energy source	Proportion (in %)	Primary energy factors (in MJ-eq/MJ)	Eco-factors (in eco-points/MJ-eq)	Environmental impact (in eco-points*10^6)
Nuclear energy	1.90	4.22	0.506	1.18
Hard coal	75.00	3.94	0.506	43.37
Natural gas	14.60	2.22	0.506	4.76
Petroleum products	1.00	3.73	0.506	0.55
Renewable energies	7.50		0.349	0.76
Sum				**50.61**

Source: Own calculation, based on Wellge, 2015; Itten and Frischknecht, 2014 and Ahbe et al., 2014

The table above represents the environmental impact of the primary energy supply, which does not include the generation of final energy. In order to calculate the environmental impact caused by the generation of final energy, the corresponding air emissions need to be taken into account. In this context, the publication of Itten and Frischknecht (2014) also provides air emission factors, which are used in context of this thesis.

Table 99: Air emission factors used in context of this thesis

Energy source	Air emission factor	Unit
Nuclear energy	0.007	kg CO_2-eq/MJ
Hard coal	0.344	kg CO_2-eq/MJ
Natural gas	0.130	kg CO_2-eq/MJ
Petroleum products	0.272	kg CO_2-eq/MJ

Source: According to Itten and Frischknecht, 2014

Thus, the environmental impact caused by the generation of final energy can be calculated in analogy to the calculation represented in Table 98. Nevertheless, the air emission factors replace the primary energy factors and the eco-factors for CO_2-equivalents are inserted in order to conduct the environmental impact assessment.

The following table provides an overview of the calculation of environmental impact caused by final energy generation in form of electricity:

Table 100: Calculation of the environmental impact caused by the final energy generation

Energy source	Proportion (in %)	Air emission factors (in kg CO_2-eq/MJ)	Eco-factors (in eco-points/ g CO_2-eq)	Environmental impact (in eco-points*10^6)
Nuclear energy	1.90	0.007	0.015	0.06
Hard coal	75.00	0.344	0.015	112.25
Natural gas	14.60	0.130	0.015	8.26
Petroleum products	1.00	0.272	0.015	1.18
Sum				**121.75**

Source: Own calculation, based on Wellge, 2015; Itten and Frischknecht, 2014 and Ahbe et al., 2014

Finally, the total environmental impact of the electricity consumption caused by the transfer press can be calculated by adding up the environmental impact caused by primary energy supply and by final energy generation. Hence, the electricity consumption caused by the transfer press results in an environmental impact, which can be expressed in 172.36 eco-points*10^6 (see Table 101).

Table 101: Total environmental impact caused by electricity consumption of the transfer press

Category	Environmental impact	Unit
Primary energy supply	50.61	Eco-points*10^6
Final energy generation	121.75	Eco-points*10^6
Sum	**172.36**	**Eco-points*10^6**

Source: Own calculation

Besides the environmental impact caused by the electricity consumption, the transfer press also consumes compressed air. The corresponding environmental impact can be calculated in analogy to the electricity consumption. Therefore, it is necessary to research how much electricity is consumed in order to generate one Nm^3 of 6 bar and 12 bar compressed air.

For internal accounting of media supply costs, the electricity generation business unit of the Volkswagen Group provides conversion tables for the technical planning department. According to these conversion tables, the amount of electricity needed to generate one Nm^3 of compressed air can be expressed as follows:

Table 102: Conversion from Nm^3 compressed air to electricity consumption

Category	Conversion factor	Unit
Compressed air (6 bar)	0.112	kWh/Nm^3
Compressed air (12 bar)	0.141	kWh/Nm^3

Source: According to Gadiel, 2015

On the basis of these conversion factors, the consumption of compressed air of the transfer press can be transferred to the corresponding electricity consumption. This conversion is expressed in the following table:

Table 103: Conversion of compressed air to the corresponding electricity consumption

Resource flow	Consumption	Conversion factor	Corresponding electricity
Compressed air (6 bar)	10,531,655 Nm^3/a	0.112 kWh/Nm^3	1,179,545 kWh/a
Compressed air (12 bar)	96,970 Nm^3/a	0.141 kWh/Nm^3	13,673 kWh/a
Sum			**1,193,218 kWh/a**

Source: Own calculations on the basis of Volkswagen, 2014c and Gadiel, 2015 [data adjusted according to secret factor]

As a consequence, the subsequent steps are conducted in analogy to the calculation of the environmental impact of the electricity generation. Hence, the corresponding electricity values are multiplied with 3.6 in order to convert them to the unit MJ. These values function as inputs to be multiplied with the corresponding energy source proportions, primary energy factors, air emission factors and eco-factors. The following tables comprise the aggregated results of these calculations:

Table 104: Calculation of total environmental impact caused by compressed air consumption (6 bar)

Category	Environmental impact	Unit
Primary energy supply	7.41	Eco-points*10^6
Final energy generation	17.82	Eco-points*10^6
Sum	**25.23**	**Eco-points*10^6**

Source: Own calculations

Table 105: Calculation of total environmental impact caused by compressed air consumption (12 bar)

Category	Environmental impact	Unit
Primary energy supply	0.08	Eco-points*10^6
Final energy generation	0.21	Eco-points*10^6
Sum	**0.29**	**Eco-points*10^6**

Source: Own calculations

Finally, the total environmental impact can be calculated for the transfer press by aggregating the eco-points of electricity consumption as well as 6 bar and 12 bar compressed air consumption:

Table 106: Calculation of total environmental impact of the transfer press

Category	Environmental impact	Unit
Electricity	172.36	Eco-points*10^6
Compressed air (6 bar)	25.23	Eco-points*10^6
Compressed air (12 bar)	0.29	Eco-points*10^6
Sum	**197.88**	**Eco-points*10^6**

Source: Own calculations

Appendix 4 – Checklist for application of the integrated investing method

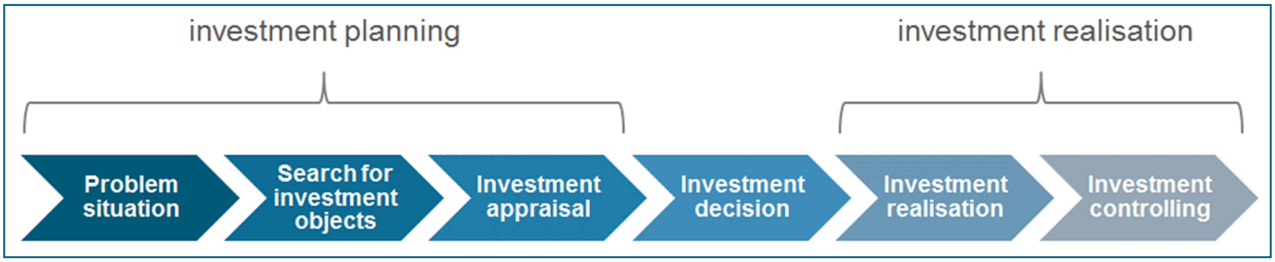
This appendix intends to provide a quick starting guide for practitioners who are willing to apply the integrated investing method within a company. Hence, the core concepts are explained shortly which systems or information is needed in order to implement the integrated investing method and who should be responsible for applying the integrated investing method. The checklist at the end of this appendix provides a quick first analysis of the current situation in order to identify further steps for implementation.

Systems and information necessary for a successful application

Single investments

When applying the integrated investing method on single investments, the most important precondition is a structured and standardised investment process. This investment process might be company specific. The integrated investing method as described in this thesis suggests the following phases:

Figure 90: Suggested investment phases for applying the integrated investing method in companies



Source: Own illustration, according to Prätsch et al., 2012 and Poggensee, 2011

However, the investment process can also be narrowed down to the three main phases of investment planning, investment decision and investment realisation. Besides a standardised investment process, it is important to determine the stakeholders involved and their responsibilities.

The table below suggests the minimum of involved stakeholders and their responsibilities:

Table 107: Suggested minimum of involved stakeholders and their responsibilities

Department	Responsibility
Technical planning	- Identify technically feasible investment objects, - Ensure technical realisation
Environmental management	- Avoid violation of given threshold values - Ensure data validity with environmental information system
Management accounting	- Conduct a fair investment appraisal - Keep within budget
Executive management	- Take investment decision
Procurement	- Ensure best conditions
Operating personnel	- Operate investment object - Provide feedback

Source: Own representation

Since the table above is subject to company-specific situations, additional responsibilities need to be determined regarding the documentation of the investment project, especially within the shared investment database. In this context, the main responsibility is at the project manager, but several specific aspects can also be entered by the employees of the environmental management and management accounting department into the shared investment database. The aim is to keep the investment database up-to-date in order to guarantee a valuable knowledge exchange and to manage and control strategic goals on an aggregated level.

Besides these systematic framework conditions, precise data regarding the investment objects are important, especially within the planning phase. In order to conduct an investment appraisal as suggested by the integrated investing method, the following data are necessary:

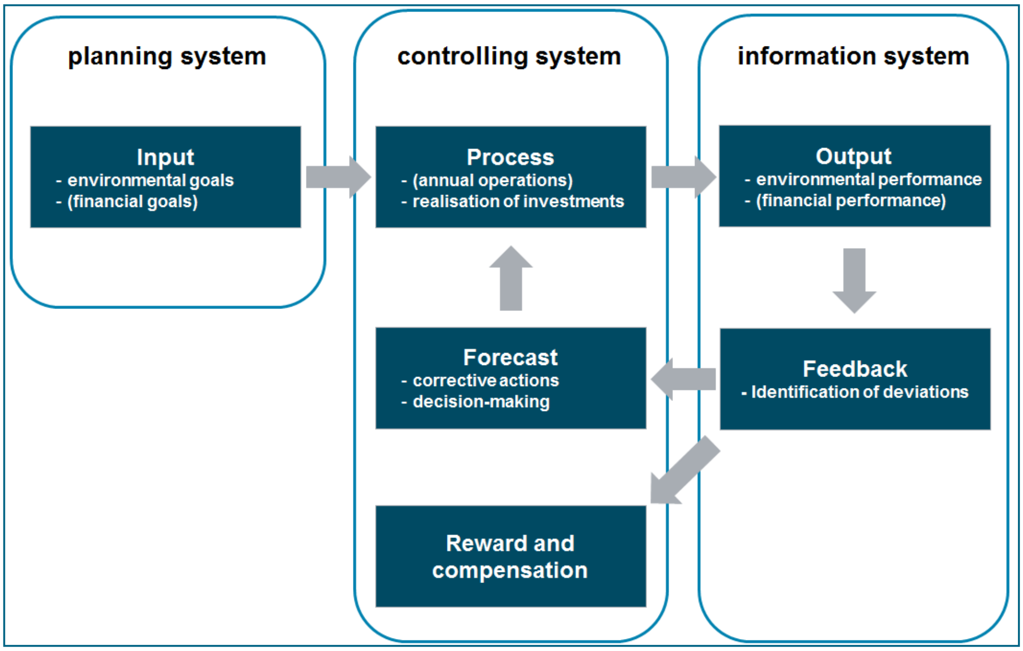
- Financial data:
    - Capital expenses of the investment alternatives
    - Operating expenses of the investment alternatives
    - Operating expenses of the current object or the state-of-the-art object as a reference
- Environmental data:
    - Expected resource and emission flows of the investment alternatives per year
    - Measured resource and emission flows of the current object or the state-of-the-art object as a reference
    - Set of eco-factors for the specific country under consideration

Finally, the execution of constant validity checks in all phases of the investment process is important to guarantee that the reduced environmental impact by an investment is also mirrored in the shared environmental information system. Hence, the investment controlling phase after realisation is important as well.

Management and Control of environmental goals

The successful integration of environmental impacts in single investments is one part, but the systematic integration within a management control system (MCS) is another important part in order to ensure the achievement of strategic environmental and financial goals. This MCS should at least contain the elements, which are illustrated in the following figure:

Figure 91: Management control system in aiming to control and achieve strategic environmental goals



Source: According to Schäffer, 2013; Zhang, 2014; Strauß and Zecher, 2013

First of all, the company should have strategic environmental goals which are quantified and thus expressible in eco-points. In addition, the environmental goals should comprise a quantified reduction target on basis of a base year to be achieved within the target year. Depending on the size and complexity of the organisation, it is helpful to allocate the reduction target to the relevant business units, enabling to formulate target amounts of eco-points for each business unit and each year.

Furthermore, a shared environmental information system tracks the resource and emission flows of the company's operations. It is important that the reports on current environmental performance have the same scope (i.e. comprise the same resource and emission flows) as the strategic environmental goals. In order to ensure the validity of the reported environmental performance data, measuring points are recommended. Furthermore, the scope of measurement should ideally be set on equipment level. Nevertheless, since this is mostly not the case in practice, the biggest and therefore most relevant machines with regard to resource consumption or emissions should be equipped with own measuring points. In addition, a responsible person, mostly located in the environmental management department, should be responsible for conducting validity checks and for keeping the environmental performance measurement up-to-date.

Regarding reporting intervals of actual environmental performance data, the reporting should align to the already established internal financial reporting interval. Ideally, the environmental performance data is sent directly within the same document as financial performance data to represent the equal valuation of strategic environmental and financial goals (i.e. integrated internal reporting). A shared database containing information regarding the status of planned and realised single investments is crucial for forecasting the effects of the investment decisions. The information entered into the data base should ideally comprise the following items:

- Name and ID of the investment measure
- Responsible planner
- Status
    - 1. Problem identified
    - 2. Information requested
    - 3. Investment decided
    - 4. Investment realised
    - 5. Investment controlling
    - 6. Investment rejected
- Description of the current situation
    - Functions and performance data
    - Resource and emission flows
    - Delimitation
- Description of the ideal situation
    - Target functions and performance data
    - Target resource and emission flows
    - Delimitation
- Time plan with project phases and corresponding deadlines
- Names and models of investment objects
- Supplying companies
- Purchasing prices
- Detailed operating costs
- Resource and emission flows
    - Physical quantities
    - Input-output model or flow model
- Excluded investment alternatives and corresponding reasons for exclusion
- Map with investment alternatives
- Ranking of investment alternatives
- Decision about the chosen investment object and the corresponding reasons
- Upload of contract including specifications
- Upload of signed record of delivery
- Location of metering points
- Deviations, their reasons and the lessons learned
- Measured resource and emission flows
- Impact on strategic environmental and financial goals

Depending on the type of investment, the company-specific definition of the investment process as well as the company-specific organisations and their corresponding responsibilities, this list might be subject to modification. For a better management and control, it is also helpful to enter relevant operational measures into the shared database that have a significant impact on the achievement of strategic environmental and financial goals. Furthermore, it is helpful to directly integrate this database to the shared environmental information system to ensure increased data validity regarding environmental performance data.

Finally, the reward and compensation system needs to acknowledge the achievement of strategic environmental goals. Depending on the reward and compensation system of the company, the achievement of the strategic environmental goals can be represented by a part of the management bonus, for instance.

Responsibilities for application of the integrated investing method

The integrated investing method represents an interface between the two cross-sectional systems of management accounting and environmental management. In the majority of companies, these two systems operate independently from each other. However, the integrated investing method requires increased collaborations of both systems. Nevertheless, professionals from both systems can remain at their area of expertise. While the environmental management accounting is concerned with the measurement of resource and emission flows and its aggregation within the shared environmental information system, the management accounting system executes its conventional tasks which are expanded by adding environmental impact assessments in form of eco-points within its investment process. Yet, this addition of environmental impact assessment can be conducted in a standardised way. A template in form of an Excel spreadsheet enables to calculate the eco-points of each single investment alternative. The only data that needs to be implemented are the resource and emission flows. This is actually the point at which both cross-sectional systems meet and therefore need to cooperate.

While the integrated investing method allows both cross-sectional systems to keep within their fields of expertise, there needs to be one person who is responsible for the first integration of the integrated investing method. Ideally, two persons would need to be assigned with this task – one person from the environmental management department and one person from the management accounting department. In case, one person is assigned as responsible, a white paper of the green controlling working group of the international controlling association (ICV) recommends the management accountant as process owner (Berlin *et al.* 2015). The underlying reason is that the management accountant already executes a business-partner approach with regard to executive management consultations.

Finally, the quick-check for an analysis of the current situation is represented as follows:

Table 108: Quick-check for analysing the current situation before applying the integrated investing method

Question	Yes	No
• Is a **standardised investment process** established, including defined investment phases, involvement of all relevant stakeholders and clear definition responsibilities?		
• Are the following **financial and environmental data** available? - Financial data: o Capital expenses and operating expenses of the investment alternatives o Operating expenses of the current object or the state-of-the-art object as a reference - Environmental data: o Expected resource and emission flows of the investment alternatives per year o Measured resource and emission flows of the current object or the state-of-the-art object as a reference o Set of eco-factors for the specific country under consideration		
• Are **validity checks** of the above-mentioned data conducted regularly?		
• Are **quantified environmental goals** established, which can be expressed in eco-points? • Do these goals contain a base year, a target year and a quantified reduction target?		
• Is a shared **environmental information system** established? • Is the corresponding environmental data in form of resource and emission flows measured via metering points? • Is it possible to measure at least the most relevant machines in terms of resource consumption and emissions? • Is the validity of the corresponding environmental data regularly checked? • Is an internal reporting interval established for environmental performance data?		
• Is an **investment database** established tracking the status of planned and realised investments? • Does the database comprise the following items? - Name and ID of the investment project - Name of responsible person - Status - Description of the current situation and ideal situation - Time plan with project phases and corresponding deadlines - Names and models of investment objects incl. supplying companies - Purchasing prices and detailed operating costs - Resource and emission flows - Excluded investment alternatives and corresponding reasons for exclusion. - Map and ranking of investment alternatives - Documented decision about the chosen investment object and the corresponding reasons - Contract including specifications and signed record of delivery - Location of metering points - Deviations, their reasons and the lessons learned - Measured resource and emission flows - Impact on strategic environmental and financial goals		
• Is a **reward and compensation system** established acknowledging the achievement of strategic environmental goals?		

Source: Own representation

In case, any assistance is needed or questions remain unanswered, please write an email to: simon@integrated-investing.com

Room for notes: