Master thesis

Carbon footprint

A case study analysing the impact of environmental influences conducted in an enterprise located in Austria

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Affidavit

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly indicated all material which has been quoted either literally or by content from the sources used. The text document uploaded to TUGRAZonline is identical to the present master‘s thesis.

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Acknowledgements

Selecting the ideal topic is always difficult, inspired by my bachelor's thesis, which dealt with quality management, the choice fell to environmental management. I selected this topic not only through actual references in politics and company management but also because of the importance of guaranteeing a future worth living.

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Abstract

Since the joint signature of the Kyoto Protocol and the Paris Agreement, climate protection has been of official national importance to the contracted countries. The industry sector is one of the biggest contributors to global warming effects. Based on this fact, this thesis presents a method to calculate the corporate carbon footprint at a manufacturing enterprise in Austria. The goal of this study is to identify the environmental impact and main emissions sources of the investigated company by using carbon dioxide (CO_2) equivalents. Based on the generated results of the calculation, individual strategies and possible improvements are developed to reduce emissions and pollution.

The carbon footprint is calculated by weighing a variety of factors, in accordance with the requirements of the Greenhouse Gas Protocol. Before starting the calculation procedure, the system boundaries for the specific object of investigation has to be defined, and an inventory analysis facilitated a clear input-output analysis of material and energy flows. Different methods of data generation and assumptions, individually adjusted for the investigated company, are necessary. The results generated indicated initial approaches for future actions that could be implemented to reduce emissions.

In contrast to the expectations within a manufacturing enterprise, the calculation identified deliveries as the main contributor to greenhouse gas pollution, followed by the energy directly consumed for operations processes. The overall produced emissions amount is 18.683 tonnes of CO_2-equivalents over the one year of the investigation. To use these results as a strategic management tool, the methods of operational greenhouse gas management is exemplified. Furthermore, possible methods to reduce the amount of CO_2-equivalent emissions are developed to save energy through modifying employee behaviour, investing in renewable energy and renewals on the shop floor, or developing strategies related to how deliveries can be handled in a more efficient manner.

In summary, carbon footprint calculations are a useful tool to identify internal potential for improvement in order to take actions in the appropriate fields of operations. Because the system boundaries and the assumptions of a carbon footprint are not globally fixed, applying this study's findings to other companies is currently not possible. In order to ensure truthful statements, especially if payments on emissions arise, further standards must be published.

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List of Abbreviations

°C	degree Celsius
CCF	Corporate Carbon Footprint
CDM	Clean Development Mechanism
CER	Certified Emission Reduction Credits
CF	Carbon Footprint
CH_4	Methane
CO_2	Carbon dioxide
CO_2-equ	Carbon dioxide-equivalent
EMAS	Eco Management and Audit Scheme
ERU	Emission Reduction Units
ERC	Emission Reduction Credits
ETS	Europe Emissions Trading System
FMEA	Failure Mode and Effects Analysis
g	Gram
GHG	Greenhouse Gases
Gt	Giga tonne
GWP	Global Warming Potential
GWP_{100}	Global Warming Potential considering a time horizon of 100 years
H_2O	Water vapour
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JI	Joint Implementation
km	Kilometre
kWh	Kilowatt hours
m^3	Cubic meter
N_2O	Nitrous oxide
NDC	National Determined Contributes
NF_3	Nitrogen trichloride
O_3	Ozone
PCF	Product Carbon Footprint
PFCs	Perfluorocarbons
Pkm	Passenger–kilometre
RPN	Risk Priority Number
SD	Sustainable Development
SF_6	Sulphur hexafluoride
SWOT	Strengths, Weaknesses, Opportunities, and Threats
t	Tonne
Tkm	Tonne-kilometre
UNFCCC	United National Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute

1. Introduction

Climate protection and adaptation to the consequences of climate change are not only social, economic, and technological challenges of the present-day but also of the future. Therefore, identifying options for action is essential (Mahammad, 2009, p. 10).

In recent years, climate change has gained importance among governments and new policies have been set, and thus, the identification and accurate quantification of GHGs have become key challenges. Corporate actions, such as quantifying greenhouse gas (GHG) emissions, are an opportunity for companies to identify or reduce risks, determine competitive advantages, and create good business sense. New market-based incentives are provided to reduce emissions, and guide economic growth along a low-carbon route. Companies must consider such policies concerning future investments. (WRI; WBCSD, 2011, p. 3)

Since the industrial revolution, the energy required for economic growth increased rapidly, and furthermore, human activities increasingly affected the natural balance on earth. The industry is identified as one of the main contributors to climate change and causes 21% of the emissions. Additionally other sectors such as electricity production and the transport are directly linked to industry and covers in total more 59% of the total amount of GHGs. With an increase in the environmental performance of the industry, also the other sectors profit from this. (IPPC, 2015, p.88)

Along with awareness for sustainable management, different methods for climate-friendly business models have been established by various institutions. Common standards and norms guide companies in the right direction, but the identification and implementation of the correct ones are a complicated process with a great variety of variables and assumptions to be estimated. This thesis exemplifies some of these methods within a company located in Austria.

1.1. Objectives

The general objective of this thesis is to determine and visualise the current situation regarding the environmental impact of Pankl. This impact is analysed through accounting GHGs, which are then translated into carbon dioxide equivalents (CO_2-equ) to make them comparable. This accounting is executed in the form of a carbon footprint calculation; therefore, an appropriate calculation model has to be chosen and a scope individually adjusted for the company under investigation has to be selected. Based on the results, opportunities for actions are identified and strategies ensured to enable a sustainable future, rounded out with a critical reflection of the company’s activities.

1.2. Initial Situation

The object of investigation is the company Pankl considering all locations in Austria. Based on the company structure, five different environmental management departments exist, as a result the implementation of new standards is difficult. Additionally, uniform data maintenance, data structure and central data management are not given. The base foundation of consideration is an implemented and certified environmental management system within the observed company (ISO 14001:2015). The most essential data to fulfil this certification are already collected and visualised in Microsoft Excel sheets, and this includes primary energy sources. Taking a closer look to these sheets the method of data collection, e.g. for transportations or the nmumber of used materials, are different from division to division and also not well elaborated. This leads to falsification of the results and a misinterpretation of the environmental performance. A fundamental method of ensuring the success of the ISO 14001:2015 is the continuous improvement process, which includes a critical self-reflection. This critical self-reflection is based on a mere presumption linked to the fact that no meaningful data are available, which can be considered cause for thought and the first step of this thesis. For effective management, essential statements must be verified with proven data and based on this information the carbon footprint calculation should deliver the necessary evidence.

1.3. Method

The first milestone of the thesis is intensive literature research, to identify feasible options for the method of GHG accounting. The objects and requirements of different standards for the carbon footprint calculation are compared and rated against each other. Based on the selected standard, the necessary data is identified. The sources used to generate the data are on the one hand company’s internal data, which are collected from waste management or electricity invoices and readings of actual accounts, or rather other records. On the other hand, for data that are not available, not documented at present, or cannot be sourced from business partners, a representative survey is employed to generate knowledge about the individual transport of employees. For the logistical execution of the survey, an external company is responsible for, the quantitative formulated questions by using multiple choice or simple numerical responses are sent to 1036 participants.

Additionally, for the selection of fitting CO_2-equivalents to the generated data, the literature, manufacturer specifications and information from engaged external cooperation partners are conducted.

Based on the calculated results, the recommendations and strategies for influencing carbon footprints positively require second literature research. Within these steps concrete suggestions for the leading producers on GHG can work out.

1.4. Structure

Bearing the objectives, the initial situation and the method in mind, the thesis is divided into two main parts.

Theoretical Part (Chapter 2, 3, and 4):
The theoretical part provides the foundation for a cautious approach based on a literature review. First, the current global situation is elucidated to clarify the relevance and elementary environmental processes. Relevant terms are defined to ensure a common understanding of the topic. The thesis continues with different environmental agreements, norms, and standards, which are essential approaches for achieving the objectives. Furthermore, the various methods of calculating carbon footprints are exemplified and presented.

Practical Part (Chapter 5, 6, and 7):
The practical part transforms the generated theoretical information into actions. The first target of the thesis is to identify the current situation of the investigated company, analyse the flow of data, and understand the existing environmental management system. Based on the generated facts and knowledge gained from the literature, the individual right model of calculation is identified for the company under observation. In the next step, the system boundary is determined and the necessary assumptions are set. With the defined framework and data generated through internal notes, external partners, and an employee survey, the calculation can be finally executed. The overall result, which demonstrates the environmental impact of the company by means of CO_2 equivalents, is visualised graphically. The last goal is to identify strategies on how an enterprise can positively influence its carbon footprint and how the calculation can be used as a strategic tool.

2. State of the Art

The term 'climate change' is defined according to IPPC (2013, p. 1450) as '*a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.*'

The climate system within the changes are happening, are divided into different categories. IPCC (2015, p. 121) defines the following components for a climate system:

- the atmosphere
- the hydrosphere (oceans and other water bodies)
- the cryosphere (ice and snow)
- the lithosphere (land surface)
- the biosphere (living things)

Humans influence the climate system; starting from the industrial revolution to the present-day, changes in human and natural systems are visible. One reason for climate change is that the climate system is not in balance anymore; the atmosphere and oceans have warmed and huge amounts of snow and ice have melted, which has led to a rise in the global sea level and numerous heavy weather events. Climate change does not only amplify existing risks but also creates new and possibly unbearable risks. To underline the enormous impact of human activities on climate change during the last century, the following figures are presented. (IPCC, 2015, p. 2 ff.)

Figure 1 visualises how earth's surface temperature has statically risen over the last three decades, and that currently is the warmest period of the last 1400 years in the Northern Hemisphere. From 1880 to 2012, a globally averaged temperature increase of land and oceans has resulted in a surplus of 0.85°C. (IPCC, 2015, p. 2 ff.)

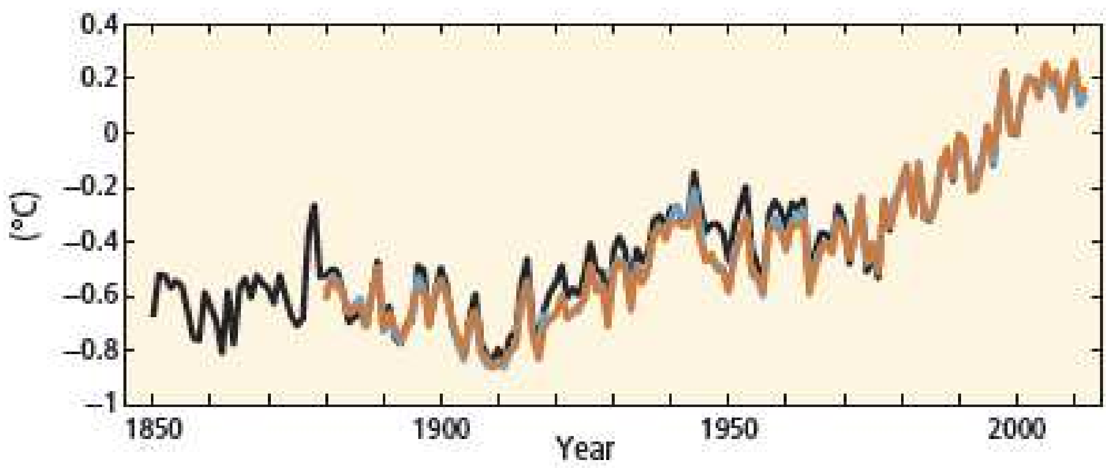

Figure 1: Globally averaged combined land and ocean surface temperature (according to IPCC, 2015, p. 3)

Additionally, Figure 2 plots the average increase in sea levels caused by Greenland and Antarctic ice sheets losing mass, glaciers shrinking, and spring snow cover decreasing. Over a century, the global mean sea level rose by 0.19 m, which is more than the total rise in the previous two millennia. (IPCC, 2015, p. 2 ff.)

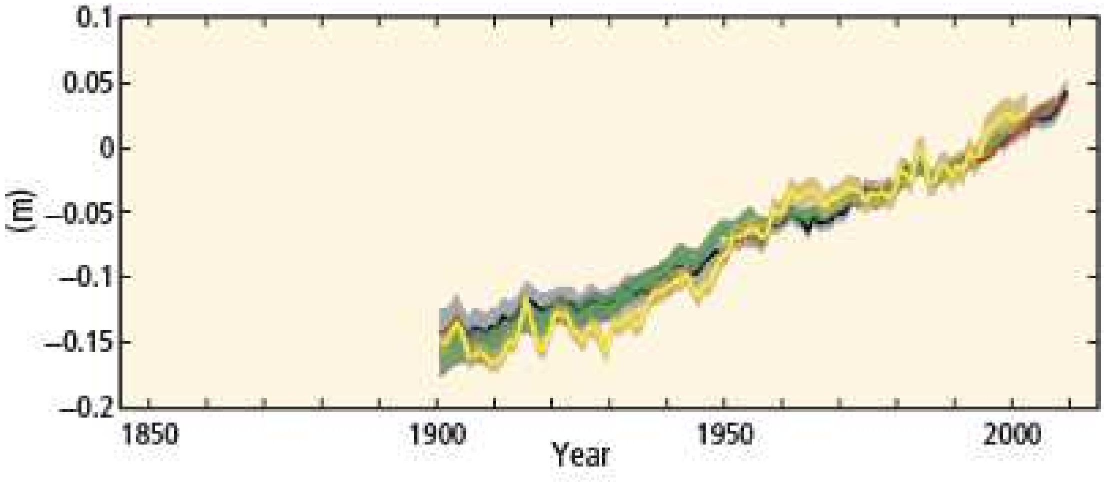

Figure 2: Globally averaged sea level change (according to IPCC, 2015, p. 3)

In sum, climate change has affected life on earth. In just 100 to 120 years, humans have caused irreversible damage to the environment. Therefore an imortant aim is to limit further increases in global warming and rising sea levels.

2.1. Greenhouse Gases (GHGs)

Global warming and increasing sea levels accompany the rising concentration of GHGs. GHGs are gaseous components in the atmosphere that can occur naturally or anthropogenically and have a direct influence on the greenhouse effect (see section 2.2). Anthropogenic GHG emissions are mainly caused by economic and population growth and have increased steadily ever since the preindustrial era. These gases, in combination with clouds and aerosols, absorb and emit terrestrial radiation that is given off by the Earth's surface or atmosphere. This leads to a heat-trapping effect, which makes the Earth's surface habitable for humans, other living creatures, and vegetation. (IPPC, 2013, p. 1455)

Table 1 lists the most important GHGs according to the Kyoto Protocol (see subsection 2.3.1), considering their lifetimes in the atmosphere and their global warming potential (GWP). GWP is used as an index for measuring the radiative force of a unit mass of a given substance accumulated over a chosen time horizon, compared with a reference substance (carbon dioxide). It estimates the combined effect of substances' residence time in the atmosphere and their effectiveness at causing radiative forcing. (IPCC, 2015, p. 124)

The first five greenhouse gases (H_2O, CO_2, N_2O, CH_4, and O_3) are defined as primary GHGs in the atmosphere, and they can occur naturally as well as anthropogenically. By contrast, the last four (SF_6, HFCs, PFCs, and NF_3) are only human-made GHGs (IPPC, et al., 2013, p. 1448 ff.)

GHG Descriptions	GWP_{100}	Lifetime (years)
Water vapour (H_2O) Water vapour is recognised as one an essential natural GHGs, but it is not part of the Kyoto Protocol. It originates from central parts of the water cycle (e.g., oceans, evaporation, and precipitation). H_2O has no direct impact, yet acts as a type of feedback for the climate.	-	-
Carbon dioxide (CO_2) CO_2 is the primary greenhouse gas and accounts for 80% of the greenhouse effect produced by humans. It can occur naturally, such as through volcanic eruptions, and anthropogenically through burning fossil fuels, land usage, and several industrial processes. It is an odourless and colourless gas.	1	120

GHG Descriptions	**GWP_{100}**	**Lifetime (years)**
Nitrous oxide (N_2O) This is emitted into the atmosphere by nitrogenous fertilisers and factory farming. The concentration within the atmosphere is low in comparison with other gases, but the impact is higher. It is a colourless gas with a sweetish smell.	265	114
Methane (CH_4) Methane is one of the most significant natural GHGs; it is produced through animal husbandry and agriculture, as well as by landfill sites and wastewater treatment plants. It is also an odourless and colourless gas, but highly flammable.	28	9–15
Ozone (O_3) Ozone has different origins; in the troposphere, it is created by photochemical and natural reactions caused by smog, whereas in the stratosphere it is a product of the interaction between ultraviolet radiation and molecular oxygen. Consequently, ozone can only be affected indirectly by humans.	2000	
Sulphur hexafluoride (SF_6) This is an inorganic chemical compound of sulphur and fluorine, mainly used in the electrical industry and as insulation gas, such as for soundproof windows. It is the GHG that has the worst impact on the environment.	23,500	3200
Hydrofluorocarbons (HFCs) These are organic compounds between hydrogen and carbon. They are used as cooling agents as well as propellants in spray cans.	124–14,800	0.3–270
Perfluorocarbons (PFCs) These are used for the production of aluminium and semiconductors, as well as being extinguishing agents for fire protection.	7390–12,200	2600–50,000
Nitrogen trichloride (NF_3) This consists of ammonia and fluorine and is found mainly in the electronics industry in the production of liquid crystal displays and solar plants.	16,100	740

Table 1: Greenhouse gases (according to Nunez, 2019, accessed on: 24.04.2019; Umweltbundesamt, 2016, accessed on: 25.04.2019)

Presently, the concentration of GHGs in the atmosphere has reached the highest point in the last 800,000 years (Nunez, 2019, accessed on: 24.04.2019). Figure 3 illustrates the annual GHG emissions during 1970–2010; an enormous rise can be identified between 2000 and 2010. During this decade there is an annual increase of 2.2%, yet a reduction is the aspired-to goal. The right-hand side of Figure 3 shows the same calculation in 2010 with CO_2-equ altered to the actual fifth assessment report. A change of CO_2-equ values through the actual assessment report leads to a change in the total amount of GHG emissions from 49 to 52 Gt. This demonstrates that the correct assumptions of CO_2-equ have a considerable influence on the overall result of GHG emissions. (IPCC, 2015, p. 5)

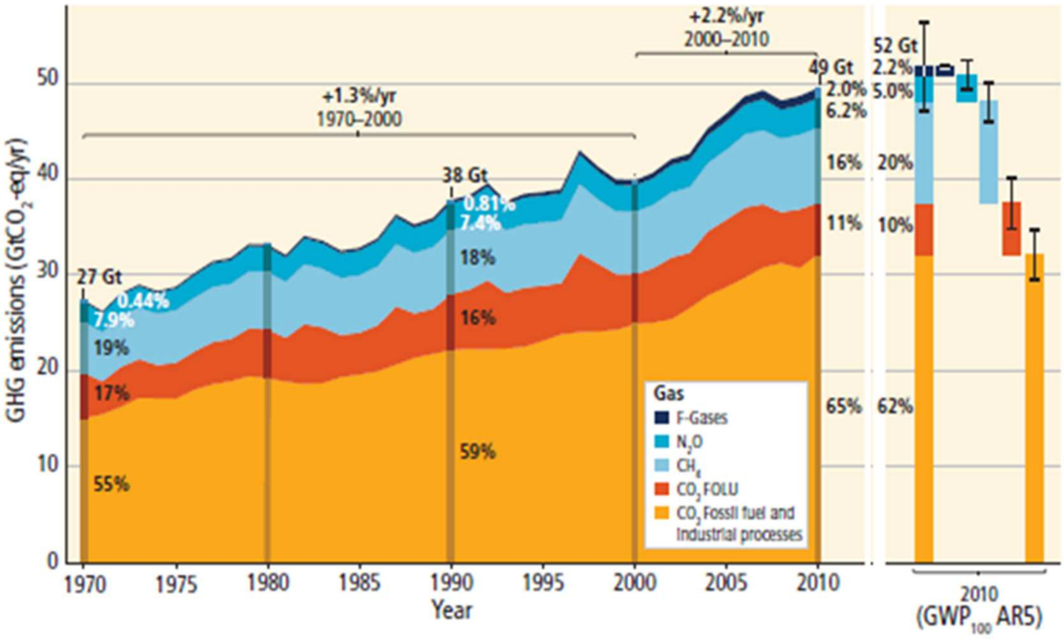

Figure 3: Total annual anthropogenic GHG emissions (according to IPCC, 2015, p. 5)

GHG emissions can be divided into various sectors that cause them. For a meaningful interpretation Figure 4, bear in mind that different time horizons can affect the result. This is because short-lived agents such as CH_4 carry another weight compared with long-lived agents and require earlier or rather more stringent CO_2 abatement. Figure 4 presents the percentage values of the contributors of produced GHGs in a time horizon of 100 years. (IPCC, 2015, p. 88)

The industry sector is the second largest contributor to GHGs, and therefore, offers the highest potential for enhancement. Considering that if the industry improves its environmental performance in the sense of resource input, energy usage, or logistics, other sectors also automatically gain additional benefits because the electricity, heat production, and transportation sectors are directly connected to the industry sector.

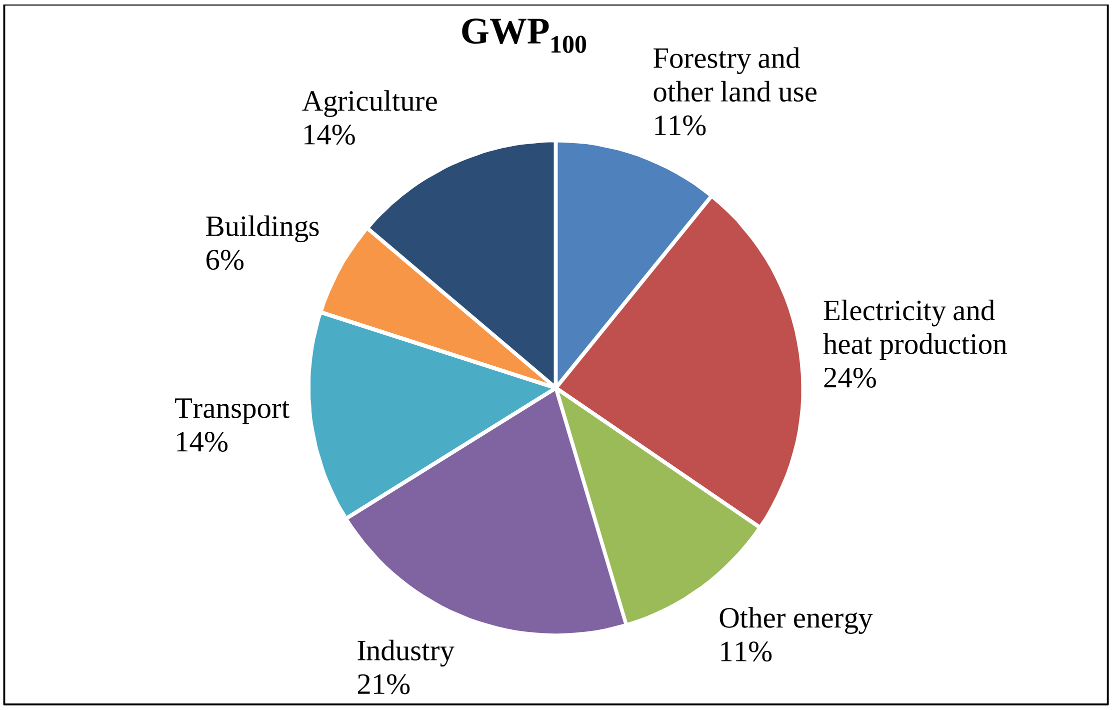

Figure 4: Contributing sectors (own illustration according to IPCC, 2015, p. 88)

In brief, both anthropogenic and natural GHGs can be identified as the main reason for the changes in the climate system. These gases can occur through various human actions, e.g. the burning of fuel, agriculture or effects in nature e.g. volcanic eruptions. For a meaningful comparison between gases, GWP and lifetime in the atmosphere must be considered. The same applies to reflect the total amount of GHG emissions and contributing sectors.

2.2. Greenhouse Effect

The greenhouse effect, which is caused by the trapping of heat through GHGs, can be divided into the natural greenhouse effect (subsection 2.2.1) and the anthropogenic greenhouse effect (subsection 2.2.2). The history and definition of this effect date back to the year 1824. The mathematician Joseph Fourier was the first person to demonstrate that the temperature on Earth would be much colder without an atmosphere. More than 70 years later in 1896, Swedish scientist Svante Arrhenius set global warming in reference to carbon dioxide. James E. Hansen proved this theory and presented his results almost a century later. Nowadays the term greenhouse effect stands for a complex system driven by GHG concentration, which is not only responsible for the increasing average temperature but also for extreme weather events, rising seas, and shifting wildlife population. (Nunez, 2019, accessed on: 24.04.2019)

Figure 5 illustrates a schematic of the greenhouse effect, which is explained in more detail in the following subsections.

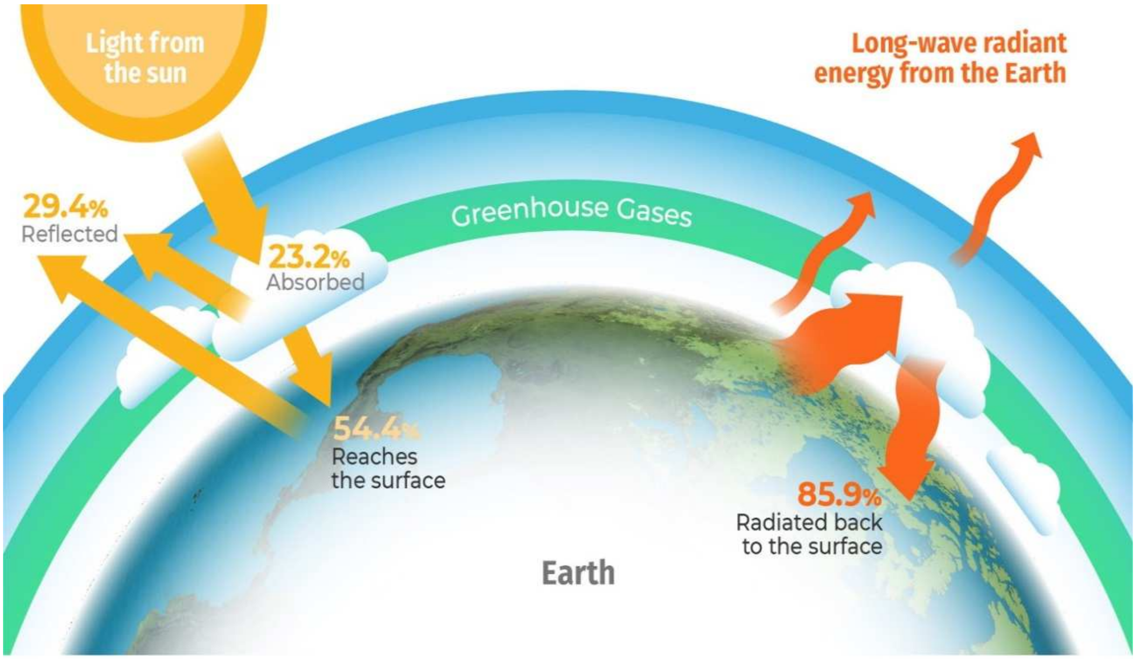

Figure 5: Greenhouse gases (according to Prairie Climate Centre, 2018, accessed on: 26.03.2019)

2.2.1. Natural Greenhouse Effect

The natural greenhouse effect is responsible for global mean temperature rises from −18 to +14°C, without this effect, life on Earth would not be possible. This is possible because one specific characteristic of the Earth’s atmosphere is that it works as a greenhouse, or in other words, a glasshouse. This phenomenon occurs because of the physical characteristic that short wave solar radiation can reach the Earth's surface unhindered, in contrast to longwave radiation (infrared radiation), which is absorbed. (Malberg, 2007, p. 320 f.)

Solar radiation is radiation emitted by the sun that enters the Earth's atmosphere. It consists of visible light, ultraviolet light, and radiation with a wavelength between 0.73 and 4.0 µm. Longwave radiation occurs from the warmed earth surface, both solid and liquid. One part of the heat goes into space in the form of infrared radiation, whereas the other returns to earth as atmospheric counter radiation. The amount of returned thermal radiation depends on the density of the atmosphere; the more GHGs there are, the higher the density. On the other side, solar radiation is reflected by GHGs and cannot reach the Earth, heating up space. (Ranke, 2019, p. 30) The gases that produce the natural greenhouse effect are H_2O, CO_2, low-lying O_3, CH_4, and NO_2 (Malberg, 2007, p. 320 f.).

2.2.2. Anthropogenic Greenhouse Effect

Additionally, to the natural greenhouse effect, the anthropogenic greenhouse effect occurs through harmful activities of humans because more climate-relevant trace gases are set free. These gases are enforced natural GHGs as well as new ones such as SF_6, HFCs, or PFCs. This causes a change in the energy and radiation balance, resulting in more radiation being absorbed. An increase in the Earth's surface temperature and troposphere heat are consequences in response to these external forces. (IPPC, et al., 2013, p. 1455) The equivalent climate impact of gases also depends on their residence time in the atmosphere, which for anthropogenic gases is many times higher than for natural gases (Ranke, 2019, p. 42).

Ranke (2019, p. 42) asserted that there are five main reasons for anthropogenic climate change:

- increase in GHGs
- deforestation of the rainforest
- urbanisation
- factory farming and intensive use of fertilisers
- excavation of raw materials for technical production

In sum, the natural greenhouse effect enables life on earth, but through human activities the anthropogenic greenhouse effect occurs, which is responsible for global warming. Therefore the goal of environmental protection is to reduce the anthropogenic greenhouse to a natural level.

2.3. Legislation

Countries worldwide have acknowledged the problem of the changing climate and implemented programmes to avoid harmful effects on the climate system. The most critical international climate protection agreement is called the United Nations Framework Convention on Climate Change (UNFCCC), which was founded in 1992 at the World Summit in Rio de Janeiro. Until today, 195 countries ratified this framework, which offers the possibility to work together for the aim of limiting the temperature rise and prohibiting further climate change. The council is responsible for two issues: the Kyoto Protocol and the Paris Agreement, which are explained in the following two subsections. (European Council, 2018, accessed on: 18.04.2019)

2.3.1. Kyoto Protocol

The Kyoto Protocol is an international agreement linked to the UNFCCC, to set internationally binding targets for reducing emissions. It was adopted on December 11, 1997 in Kyoto, Japan and entered into force on February 16, 2005. The aim of the industrialised countries that ratified it (named in appendix B of the Protocol) is to reduce GHG emissions in total by 5.2% from 2008 to 2012 compared with the emissions of 1990. The Protocol defined six GHG gases as the main root cause of the global change in climate: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. Detailed information about these gases and their GWP are described in section 2.1. The agreed contribution of the individual industrialised countries depends on their level of economic development, which means that developing countries are not considered. The next milestone was the Doha Amendment to the Kyoto Protocol on December 8, 2012, where new commitments are set, and a seventh GHG was added, namely nitrogen trifluoride (NF_3). (UNFCCC, 2019a, accessed on: 24.03.2019)

The Kyoto Protocol commits the countries to reach targets primarily through national measures, but also offers three mechanisms to meet the targets in case of nonconformance. These are optional methods intended to help members reach their prescribed reductions on paper and prevent nonconformance against the Kyoto Protocol. These flexible mechanisms according to UNFCCC (2019a, accessed on: 24.03.2019) are:

i. International emission trading

Emission trading allows countries that have ‘emissions capacity’ left to sell it to other countries. The aim is to enable them to meet their set targets. Carbon can be traded like other goods, and thus this market is known as the ‘carbon market’.

ii. Clean development mechanism (CDM)

The Kyoto Protocol set no limits on GHG emissions in developing countries; however, the sum of emissions is spread over the whole atmosphere. This mechanism allows industrialised members of the Kyoto Protocol to implement an emission-reduction project in developing countries to earn saleable certified emission-reduction credits (ERCs), which can be used to meet the set Kyoto targets in the country of origin.

iii. Joint implementation (JI)

This mechanism allows members of the Kyoto Protocol to earn emission reduction units (ERUs) for implementing an emission-reduction project in another country that is a member of the Kyoto Protocol. It follows the same principle as the CDM in that the ERUs can be used to fulfil the targets in the country of origin.

These mechanisms are flexible and cost-efficient methods of reaching the targets, but with the addition that they must be monitored and documented precisely (UNFCCC, 2019a, accessed on: 2019).

Nevertheless, one of the most significant disadvantages of the Kyoto Protocol is that only industrialised countries are part of this agreement; the maximum rate of increase in GHG emissions results from developing countries. (Bundesministerium für Nachhaltigkeit und Tourismus, 2019, accessed on: 24.03.2019)

2.3.2. Paris Agreement

The Paris agreement is a landmark agreement to combat climate change, not only to accelerate but also to intensify the required actions and investments for a sustainable low-carbon future. It is also linked to the UNFCCC, with the overall goal of maintaining the global temperature rise below 2°C compared with preindustrial times, while simultaneously pursuing efforts to limit the increase to 1.5°C. This agreement is the successor of the Kyoto Protocol and came into force on November 4, 2016; until 2019, 185 parties have ratified the convention. As a first approach, the Paris agreement places the responsibility for climate protection on all nations, with additional attention to assisting developing countries to follow these methods. (UNFCCC, 2019b, accssed on: 24.03.2019)

To achieve the overall goal, key aspects are defined in the agreement. One of them is to reach the peak of GHG emissions as soon as possible and transform to climate neutrality in the second half of this century. Furthermore, all parties must present and implement Nationally-Determined Contributions (NDC) to reduce emissions every five years, with the aim of continuous improvement. Another point is to adopt plans from specific changes because of climate change and support developing countries with capacity building, technology transfer, and financing. (Bundesministerium für Nachhaltigkeit und Tourismus, 2019, accessed on: 24.03.2019) An additional crucial point of the agreement is to maintain transparency of actions and the framework high. Furthermore, it is used to increase an understanding by means of actions regarding how to handle losses and damages caused by climate change, including extreme weather events and rising sea levels. Moreover, education, training, and public access to information about climate change are enhanced under the Paris Agreement. (UNFCCC, 2019b, accessed on: 24.03.2019)

In sum, the selected goals are ambitious and only achievable with strong commitment from all ratified countries. However, with the implementation of flexible mechanisms, a potential path is paved for reaching the goals. A disadvantage is that the wording of the agreements' aims is too vague and not all countries are obliged to maintain the global temperature rise below 2°C.

3. Environmental Management Systems

To cover the legislation, specifications and requirements signed by a country must be realised from many contributing parties. For one thing by individuals (e.g., individual road-traffic), but as already described in Figure 4 (section 2.1), almost one-quarter of emissions is directly caused by industrial activities, and another quarter is indirectly affected through activities caused by the industry. Therefore, companies must contribute heavily to the success of and compliance with agreed targets. One possibility to steer companies in the right direction is to implement an environmental management system that offers a framework for acting in an environmentally friendly manner.

An effective environmental management system ensures that the legal situation and formal requirements used for the protection of the environment are observed. One of the central points is the definition of the goals and strategy of realisation. For the implementation process, there are two significant emission permits, namely ISO 14001:2015 and EMAS III. (Hering & Schulz, 2018, p. 47)

For acting within this system, companies must pay special attention to sustainable entrepreneurial acts to ensure a long lasting and clean future. The following chapter deals with the definition of the term sustainability and its influencing factors, and provides detailed descriptions of the two abovementioned emission permits.

3.1. Sustainability

The definition of sustainability is different from source to source. One of the most popular interpretations is that of Hardtke & Prehn (2001, p. 58): '*Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.*'

Referring to this description, three factors of sustainable management—economic, environmental, and social—must be rated. The right balance of these pillars guarantees sustainable development, with this in mind Arnold (2007, p. 36) defined the factors as followed:

- **Economic sustainability** includes economic growth, economic competition, and an efficient economic system. This means that within this pillar the economic success of the company is of particular importance. Nonetheless, the protection of economic resources against exploitation is a significant subcomponent.

- **Environmental sustainability** is targeted at protecting the environment, preventing biodiversity, and reducing emissions for preserving nature and the environment for future generations.

- **Social sustainability** aims to ensure a long-term liveable and future-oriented society characterised by equal opportunities, human rights, health care, and education.

Various schematics are used to visualise the arrangement of these factors. The illustration and approach used vary over time. Figure 6, Figure 7, and Figure 8 demonstrate the most popular methods, including a short description of each. Problems occur in the practical usage of the described methods because it is difficult to define what is equally, more, or less important. The different motivations and requirements of the interested parties, as well as political, legal, cultural and religious factors, influence the framework. The conflict of objectives, short- and long-term oriented, must be solved by companies. (Raschke, 2015, accessed on: 18.04.2019)

i. Three Pillars of Sustainability

One of the most popular representations is called the three pillars of sustainability, where the pillars are arranged parallel to each other. A disadvantage of this approach is that one or two pillars can be removed without the construction collapses. Based on this, the required relationships are not provided to ensure a relieable system.

A spatial modification would ensure the required connection between the pillars; however, applications with this method are unknown. (Kleine, 2009, p. 73 ff.)

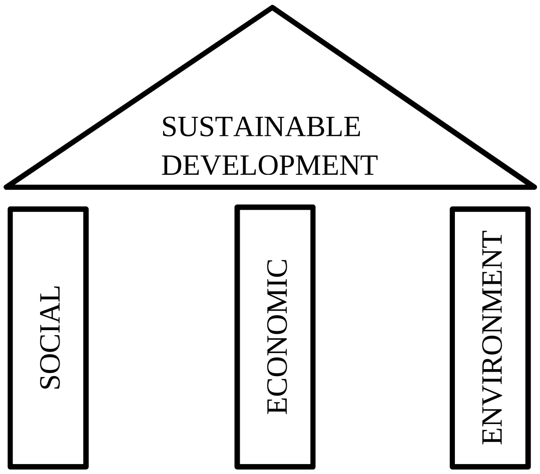

Figure 6: Three pillars of sustainability (own illustration according to Kleine, 2009, p. 75)

ii. Triangular Model of Sustainable Development

According to an equilateral triangle, every pillar is on an equal footing, which means that no one is allowed to be disadvantaged in the course of the discussion process (Kleine, 2009, p. 73 ff.). In contrast to Figure 6, within the method of Figure 7 it is not possible to change the weighting of the factors, and consequently, it is used more often in practice.

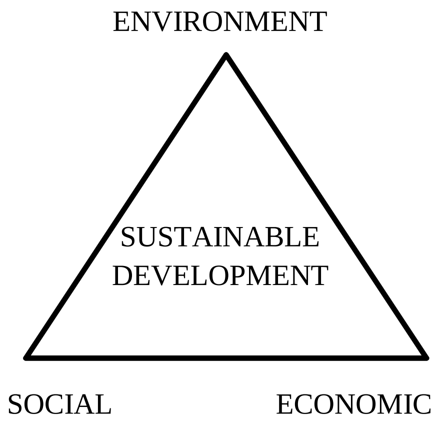

Figure 7: Triangular model of sustainable development (own illustration according to Kleine, 2009, p. 74)

iii. Integrative Sustainable Model

Environment, social, and economic factors are equally important in case of strategic objectives; the relationship between them is demonstrated in Figure 8 using a Venn diagram. The dimensions are connected with each other and the intersecting set forms the sustainable development. The other overlaps are formed between social–economic, environment–economic, and economic–social. They offer potential for new approaches. (Raschke, 2015, accessed on: 18.04.2019)

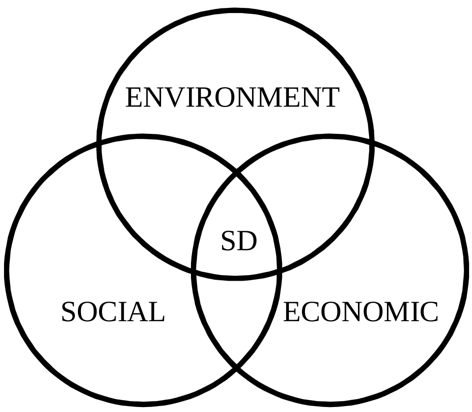

Figure 8: Integrative sustainable model (own illustration according to Raschke, 2015, accessed on:18.04.2019)

In sum, all models pursue the same strategy to act sustainable. For a company it is difficult to differentiate between the models within the practical usage. The company Pankl tries to follow the integrative sustainable model because this offers more freedom for practical implementation. Furthermore, a clear separation of the pillars – environment, social and economic – is often not possible, which suggests the integrative sustainable model. In the end, a successful balancing of the pillars is more important than to follow one specific mode.

3.2. ISO 14001:2015

ISO (International Organization for Standardization) is a worldwide federation of national standard institutions that develops and publishes international standards. The documents include requirements, specifications, guidelines, or characteristics for the optimal deployment of materials, products, processes, and services. ISO 14001:2015, developed in 1996, is an established certification for environmental management systems to act environmentally consciously and sustainably. With an efficient environmental management system, the potential is provided for reducing negative environmental impacts and raising production efficiency. (TÜV AUSTRIA HOLDING AG , 2019, accessed on: 26.03.2019)

Additionally, it offers a framework for balancing the three pillars of sustainability. The environmental management system fulfils not only the enhancement of environmental performance and fulfilment of compliance obligations but also the achievement of environmental objectives. (DIN Deutsches Institut für Normung e. V., 2015, p. 14)

For a fruitful implementation, a commitment from all levels and functions of the organisation are essential. For long-term success, a continuous improvement process based on a Plan-Do-Check-Act (PDCA) concept is used. The steps within this cycle are defined as stated by DIN Deutsches Institut für Normung e. V. (2015, p. 23) as followed:

i. Plan:

Every process must be planned before an implementation can be performed; therefore, the status quo must be analysed and objectives have to be formulated.

ii. Do:

In this phase, the implementation is conducted as planned to reach the set goals.

iii. Check:

The results are reflected, the collected experiences are analysed, and data are reported to ensure traceability.

iv. Act:

The standardisation of successful implemented actions with satisfying results are part of this step. Furthermore, the reflection of processes and identification of options for following activities lead to actions for continuous improvement.

Figure 9 presents a PCDA cycle, where it is crucial to determine a system boundary. The boundary considers not only external but also internal issues, as well as the needs and expectations of interested parties. The aim is that the intended outcomes of the environmental management system meet the requirements. Crucial for the PDCA cycle is that the organisational units, functions, and physical boundaries, as well as activities, products and services, must be defined to ensure the applicability of the environmental management system. (DIN Deutsches Institut für Normung e. V., 2015, p. 23)

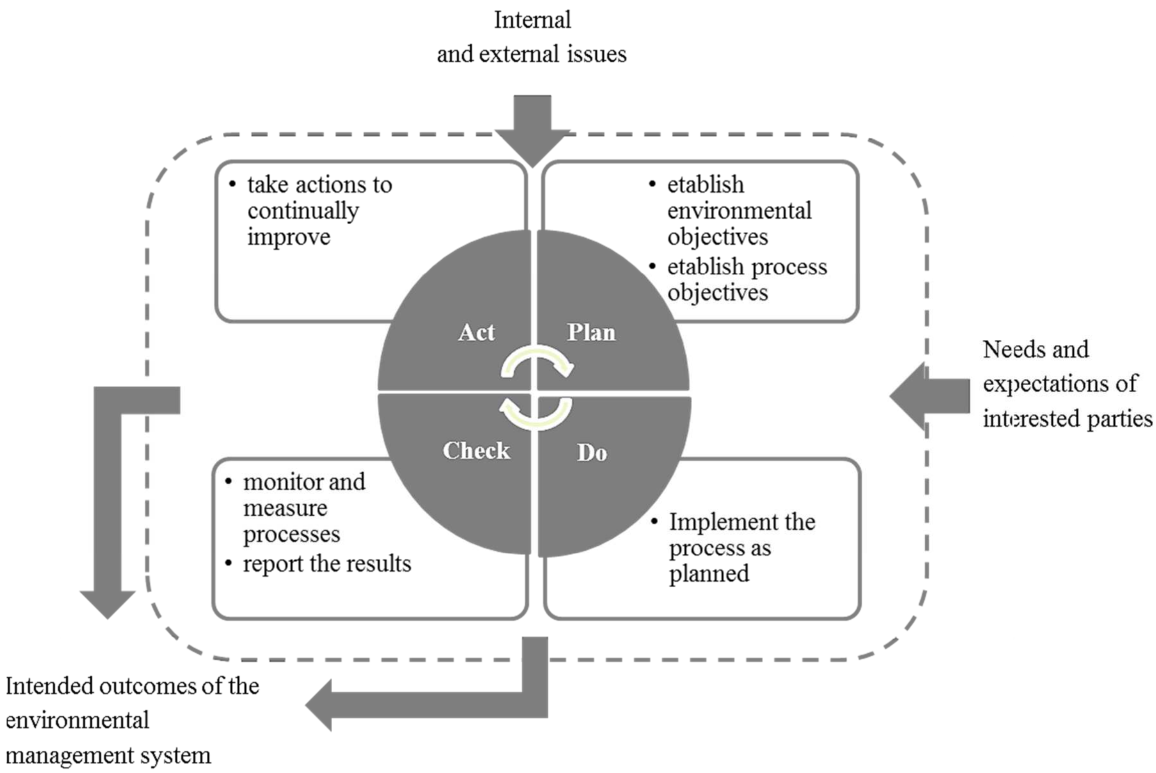

Figure 9: PDCA cycle (own illustration according to DIN Deutsches Institut für Normung e. V., 2015, p. 11)

The certification is governed by specific conditions that include documentation or rather an integration of the environmental management system, as well as an existing register of all legal obligations, and all authorised representatives are determined. (TÜV AUSTRIA HOLDING AG , 2019, accessed on: 26.03.2019)

3.3. EMAS III

Developed in 1993, EMAS (Eco-Management and Audit Scheme) is a voluntary system for companies and other organisations, which want improve the environmental performance. This method is possible for all member states of the European Union. All member states have to prepare an environmental statement, a presentation of the company's environmental policy and environment programme. Furthermore, the environmental impact of the company is evaluated, and goals for improving environmental protection are stated. (Umweltbundesamt, 2019, accessed on: 23.03.2019)

Generally, the aims of EMAS III are the same as ISO 14001:2015; it only uses other approaches to reach them. However, the following goals should be reached using EMAS III according to Bayrisches Landesamt für Umwelt (2018, p. 3):

- continuous improvement of environmental aspects
- including employees in the process
- internal and external communication about environmental protection
- identifying emergency plans

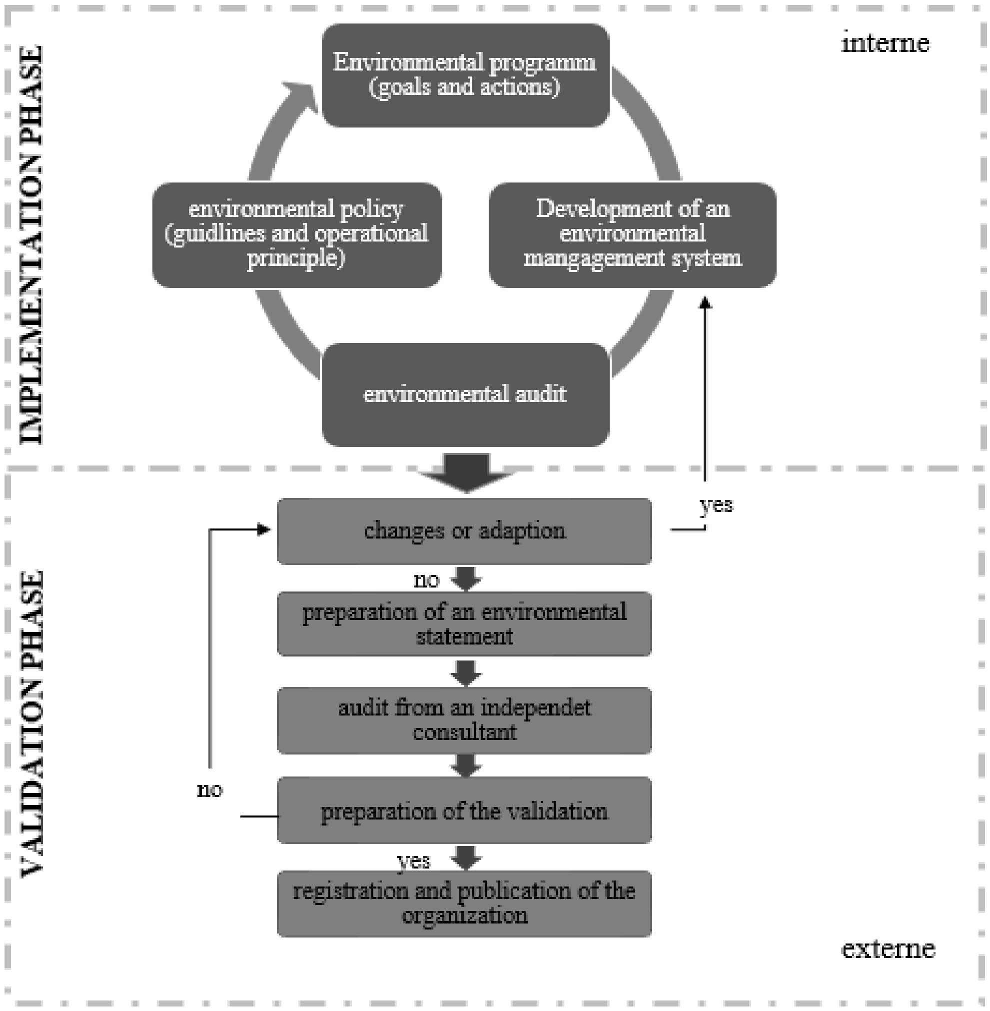

Figure 10: EMAS (own illustration according to Holze, 2004, p. 266)

As it is presented in Figure 10 the system consists of two different phases. The first is the implementation phase, which is part of a continuous improvement process and the company is internally responsible for it. The second is the validation phase, wherein the environmental performance is checked. After passing the validation, the company is registered in the list of EMAS.

3.4. General Information about ISO 14001 and EMAS

For analysing the status quo of the audited company, direct and indirect environmental aspects must be defined, the most crucial of which are listed in Table 2. Furthermore, the legal basis concerning environmental issues must be proofed and company internal responsibilities must be set.

Direct environmental aspects	Indirect environmental aspects
• Usage of resources, raw materials, and energy. • Emissions through production, wasted water, and waste. • Traffic based on deliveries. • Environmental impacts based on emergency scenarios. • Land usage of the company.	• Product- or process-related emissions. • Environmental performance of suppliers. • Capital investments. • Technology standards in foreign markets. • Assessments from a competent authority.

Table 2: Direct and indirect environmental aspects (own illustration according to Bayrisches Landesamt für Umwelt, 2018, p. 4)

As mentioned in Figure 9 as well as in Figure 10, the environmental and process objectives must be specified. This includes a definition of the environmental policy with guidelines, principles, and overall goals, as well as the environmental programme with concrete short-term goals formulated.

The environmental statement includes the following core indicators for environmental performance referencing to Bayrisches Landesamt für Umwelt (2018, p. 4 ff.):

- Energy efficiency: annual usage of energy with a separate marking of renewable energy sources
- Material efficiency: annual mass flux of individual materials
- Water: annual water usage
- Waste: annual waste generation, differentiated into harmful and harmless
- Biological diversity: land usage
- Emissions: annual emissions considering greenhouse gases and others

Table 3 provides a short overview of the main differences between ISO 14001:2015 and EMAS III to visualise the presented information. As a general rule, parties certificated with EMAS automatically fulfil the ISO standard.

	ISO 14001:2015	EMAS III
Scope	Worldwide	Europe-wide
Legal status	Norm, private commercial agreements	Current EU law
Criteria	• An environmental statement (recommended) • Determining direct environmental aspects	• The environmental statement (compulsory) • Classification into direct and indirect environmental aspects
Legal compliance	Called for an evaluation of compliance with environmental legislation	Compliance with environmental legal regulations necessary
Inspection	Certification of the environmental management system	Validation of the environmental statement
Audit	• Repeat audit every three years • Annual monitoring audit	• Revalidation every three years • Yearly examination of the environmental statement

Table 3: Differences ISO14001/EMAS (own illustration according to Stadt Graz Umweltamt, 2019, accessed on: 06.03.2019)

In general, both methods offer an ideal framework for acting environmentally friendly. The advantage of ISO 14001:2015 is its worldwide validity range and the lesser bureaucratic effort, whereas EMAS III convinces with detailed consideration of the aspects and follows the current law. The decision between the presented systems depends on the requirements of the company and the industrial settlement of customers, or rather, suppliers.

4. Carbon Footprint

This chapter deals with the definition of the term carbon footprint, including the history and various objects of reflection. It includes different methods of calculation, the framework within the calculation is implemented, and how the scope of consideration can be staked out.

4.1. Definition

As described in section 2.1, GHGs have different characteristics regarding their impact and lifetimes. To ensure that the right values of impact are used, CO_2-equ values are used according to the following definition of IPCC (2007, p. 36): *'GHGs differ in their warming influence (radiative forcing) on the global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO_2. CO_2-equ emission is the amount of CO_2 emission that would cause the same time-integrated radiative forcing, over a given time horizon, as an emitted amount of a long-lived GHG or a mixture of GHGs. The equivalent CO_2 emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon. For a mix of GHGs, it is obtained by summing the equivalent CO_2 emissions of each gas. The equivalent CO_2 emission is a standard and useful metric for comparing emissions of different GHGs but does not imply the same climate change responses.'*

Literature offers no uniform definition for carbon footprint. Experts vary not only in their wording but also in their scope of involvement. For this thesis, the most widely used terms and most exact definitions are selected.

Historically, the nomenclature of carbon footprint stems from the concept of the 'ecological footprint' of Wackernagel and Rees in the year 1994. It demonstrates how much biologically productive land and sea is required to enable the lifestyle of one person permanently. This assumption is expressed as global hectares. In this time period, the calculation of the carbon footprint also referred to the land area required to assimilate the emitted CO_2. Over time, the carbon footprint disassociated from the ecological footprint and changes to a global warming indicator. (Pandey, et al., 2010, p. 137) In subsequent years, only CO_2 emissions were considered, during which time a popular definition from Wiedmann & Minx (2007, p. 4) was published: '*The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that are directly and indirectly caused by an activity or is accumulated over the life stages of a product.'* Directly emitted emissions are caused by the process of burning fuels, whereas indirect emissions are generated by upstream or rather downstream processes (Pandey, et al., 2010, p. 137). Later, GHG emissions were included in the calculation, by means of translating them into CO_2-equ values (Wiedmann & Minx, 2007, p. 3). Based on this, Muthu (2016, p.131) mentioned a new definition: a carbon footprint is '*the quantity of GHGs expressed in terms of CO_2-equ, emitted into the atmosphere by an individual, organisation, process, product, or event from within a specified boundary*.'

Independent of its definition, the carbon footprint can always be divided into different sections with other core areas of consideration. The most crucial are the personal carbon footprint, the product carbon footprint (PCF), and the corporate carbon footprint (CCF). They will be described on the basis of their main characteristics.

i. Personal Carbon Footprint

The personal carbon footprint considers the impact of the individuum, it is divided into the following segments as reported by Schächtele & Hertle (2007, accessed on: 26.04.2019):

- Living (e.g., space heating, warm water, and energy sources)
- Mobility (e.g., cars and air traffic)
- Nutrition
- Private consumption
- General usage

The values of the produced emissions depend on the scope of the balance sheet, which varies within different frameworks (Schächtele & Hertle, 2007, accessed on: 26.04.2019).

ii. Product Carbon Footprint

The PCF illustrates all GHGs that one product produces in the course of its life phases. The consideration starts with the raw material extraction, continues with the different stages of production and the usage of the product by the customer, and is finalised with disposal and recycling. In other words, a cradle-to-gate perspective is used, and as visualised in Figure 11, all stages of the processes are passed. (BASF SE, 2019, accessed on: 28.03.2019)

The approach enables identification of the derived sectors that have the potential for improvement. Furthermore, customers are increasingly looking at the environmental impact of a product as a part of their purchase decision. (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, 2016, accessed on: 26.04.2019) This leads to the exaptation that in the future a competitive advantage can be gained by an environmentally friendly method of production.

Figure 11: PCF (own illustration according to BASF SE, 2019, accessed on: 28.03.2018)

iii. Corporate Carbon Footprint

The CCF is used for the CO_2 balance sheets of a company or organisation. It is calculated by adding all GHGs that are produced directly or indirectly by an organisation or company. As opposed to the PCF, the CCF follows a gate-to-gate perspective where only directly produced emissions are compulsory for the calculation; this segment is marked in Figure 11 in dark grey. The upstream and downstream processes are obligatory and vary according to the system boundary, which is marked in Figure 11 in light grey. (Nertinger, 2014, p. 132)

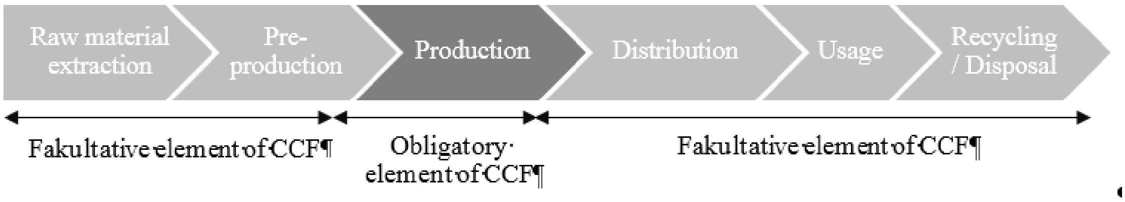

Figure 12: CCF (own illustration according to BASF SE, 2019, accessed on: 28.03.2018)

4.2. Calculation Models

Before starting the calculation, the level of detail must be defined, as an in-depth understanding of the contributing factors is essential. Therefore the Pareto principle can be applied. The Pareto principle was named after its inventor, Vilfredo Pareto, who discovered it in 1897 and associated results with effort. The so-called ‘80-20 rule’ indicates that 80% of the work causes 20% of results, and 20% of the work determines 80% of the results. (Russel-Walling, 2011, p. 68) Therefore it is clever to choose a strategic degree of abstraction to avoid an unmanageable additional expense.

According to DFGE (2012, p. 4), an experienced operator can reduce its effort significantly with only a small loss of accuracy but with massive savings in time and effort using a top-down approach. The strategy is to concentrate on items with a huge impact, which are called sensitive elements. According to an evaluation of total balance, further items are compared, assessed, and prioritised to sensitive elements. One advantage of using this strategy is that a dynamic process is possible, which is an implementation with sufficient data accuracy. However, this type of process requires much experience from the operator to guarantee that 80% of the emissions are covered and no essential emission sources are missing and ‘green washing’ or a misinterpretation of the result is the consequence.

By contrast, the bottom-up approach only describes the data collected and processed at the local level of a location; other partners are not part of the consideration. The greatest disadvantage of this calculation method is that the data accuracy depends on the responsible person and varies over time. This method is predominantly used at the smallest local sites because of the huge amount of work involved at larger locations. (Nichollos, 2015, accessed on: 30.04.2019)

The top-down and bottom-up approaches are visualised in Figure 13. The level of detail and the level of effort are described within this figure.

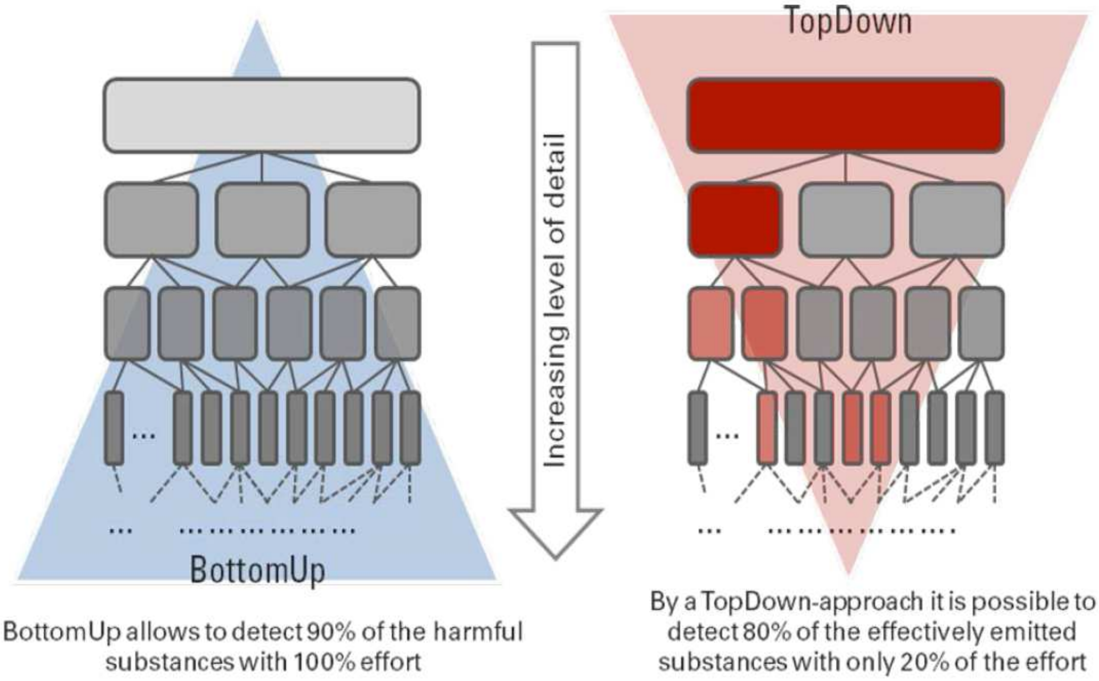

Figure 13: Bottom-up and top-down approaches (according to DFGE, 2012, p. 4)

To ensure that the carbon footprint calculations are comparable, different norms and standards have been published. The most accepted standards for calculating the CCF are the Greenhouse Gas Protocol and ISO 14064-1,-2-3 in combination with ISO 14044, whereas for the PCF, ISO 14067 is primary used. The latter concept is not explained in detail in this thesis because the practical part only deals with the CCF, based on this the focus lies on the CCF.

The aforementioned standards overlap in most of their parts but vary significantly in its approach. Nevertheless, all follow the same principles for an effective GHG balance sheet. The most critical characteristics according to Nertinger (2014, p. 133) are:

- Relevance
- Completeness
- Consistency
- Accuracy
- Transparency

Considering these five aspects, the main difference between the standards is that the GHG Protocol explains how and why to do the GHG accounting, whereas ISO 14064 establishes what to do. (Wintergreen & Delaney, 2007, p. 1 ff.).

4.2.1. Greenhouse Gas Protocol

The Greenhouse Gas Protocol is a multi-stakeholder partnership of businesses, nongovernmental organisation and governments. The international standard has the aim of reaching a low emissions economy worldwide, and was developed in 1998 by the World Resource Institute (WRI) and World Business Council for Sustainable Development (WBCSD). It provides companies with the possibility of identifying their emissions-related risks and allows them to switch their focus to relevant areas. (WRI; WBCSD, 2011, p. 3 ff.)

The GHGs observed from the GHG protocol are similar to the gases defined in the Kyoto Protocol (see subsection 2.3.1). For an effective and transparent calculation, the GHG Protocol implements three ‘scopes’ (scope 1, 2, and 3) to clarify direct and indirect emissions. Direct emissions are owned and controlled by the company itself, whereas indirect emissions are related to others and only occur through activities from its own company. Setting a clear boundary where the included operations are defined is a pivotal step in ensuring that two or more companies do not conduct double accounting with the same emissions. (WRI; WBCSD, 2004, p. 25)

Figure 14 indicates the most important steps in the calculations of this method, divided into the aforementioned scopes as well as into upstream and downstream activities.

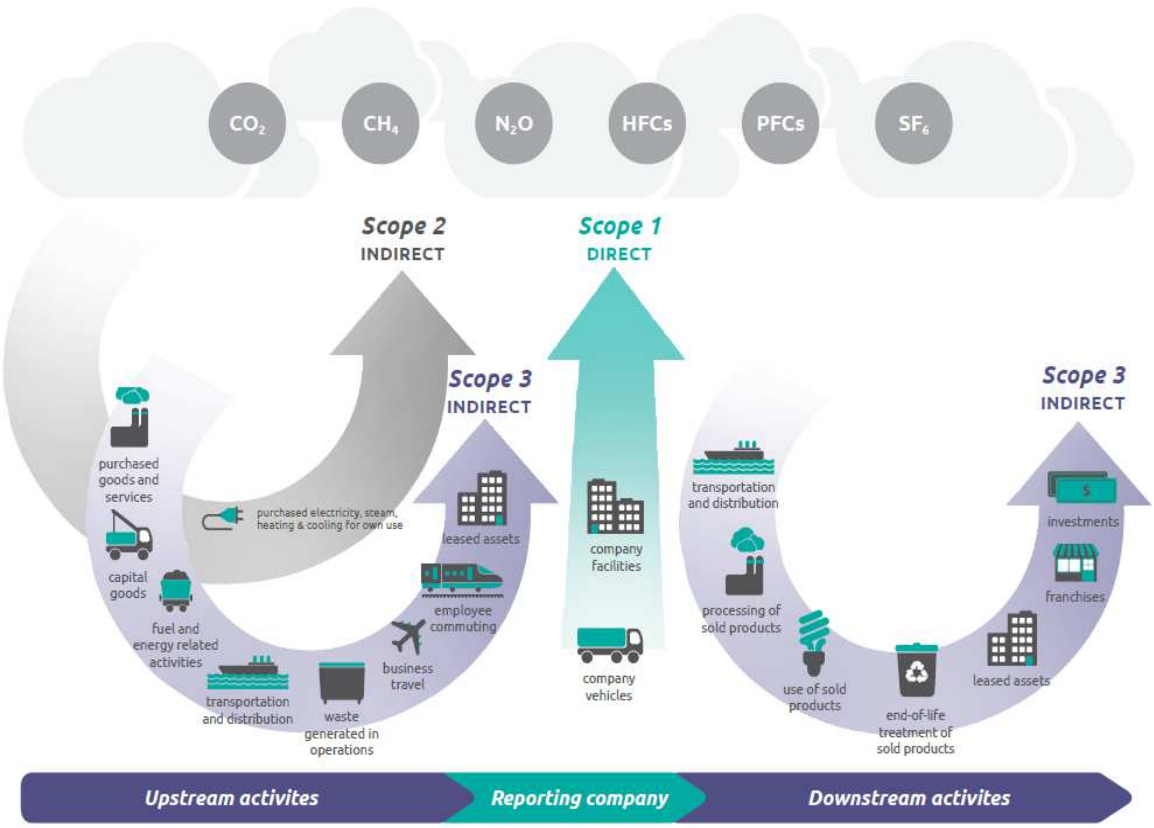

Figure 14: Overview of GHG Protocol scopes (according to WRI; WBCSD, 2011, p. 5)

To enable a better understanding of the specific scopes, the parts that belong to each scope are described below in detail, and furthermore, the individual methods of data generation are listed. (WRI; WBCSD, 2004, p. 25 ff.; EnergieArgentur.NRW, 2019, accessed on: 30.04.2019; WRI; WBCSD, 2011, p. 29)

i. **Scope 1** is defined as direct GHG emissions that occur from company-owned or controlled sources, and this includes the following activities:

- Generation of electricity, heat, or steam
  Data sources: Quantity used from primary energy sources, delivery documents, invoices, and meter readings

- Physical or chemical processing
  Data sources: Estimating production data/quantity assumed and meter readings

- Transportation of materials, products, waste, and employees in company-owned or controlled mobile combustion sources
  Data sources: Amount of fuels, driven kilometres, invoices, delivery documents, fuel cards, and mileage status

- Fugitive emissions as a result of internal or external releases
  Data sources: Determination of leakages and refilling quantity

ii. **Scope 2** considers indirect GHG emissions from the generation of purchased electricity consumed by the company or controlled equipment and operations.

- Use of purchased electricity, steam heating or cooling
  Data source: Amount of purchased goods, invoices, and meter readings

iii. **Scope 3** is optional (in contrast to the others) and implements indirect GHG emissions similar to scope 2. It is classified into upstream emissions, which include all activities for gathering goods or services, and downstream emissions, which consider all events after the production of good and services.

- Extraction and production of purchased materials or goods (upstreaming process)
  Data source: Amount of purchased goods, and invoices

- Means of production and fixed assets (upstreaming process)
  Data source: Amount can be requested in purchases, emissions can be requested by manufacturer

- Deliveries (can be an upstreaming and a downstreaming process)
  Data source: Amount of fuels, driven kilometres, invoices, delivery

documents, fuel cards, mileage status, weight of goods, and travel expense accounting

- Transport-related activities such as business travel and individual transport (upstreaming process)
  Data source: Amount of fuels, driven kilometres, invoices, delivery documents, fuel cards, mileage status, travel expense accounting, and employee survey

- Leased assets, franchises, and outsourced activities (downstreaming process)
  Data source: invoices and leases

- Use of sold products and services (downstreaming process)
  Data source: Amount of products sold, energy demand for usage, assumptions about user behaviour, and durability of the product

- Waste disposal (downstreaming process)
  Data source: Invoices, delivery documents, weight, amount of products sold and their packaging, and assumptions about recycling/disposal

The sum of all these aspects forms the total carbon footprint of a company. Separation into the abovementioned scopes paves the way for planning actions in the right area with the most potential for improvement. In addition, a clear structured framework offers the possibility for making the results comparable.

4.2.2. ISO 14044:2018

The ISO, with the norm 14044:2018 ‘Environmental Management-Life cycle assessment - Requirements and Guidelines’, provides a framework for improving environmental performance. It allows interested parties to identify critical phases along the value chain of a product, process, or service. It includes organisational aspects, such as the involvement of critical review processes, as well as technical aspects of a project. (Grösser, 2017, p. 98 ff.)

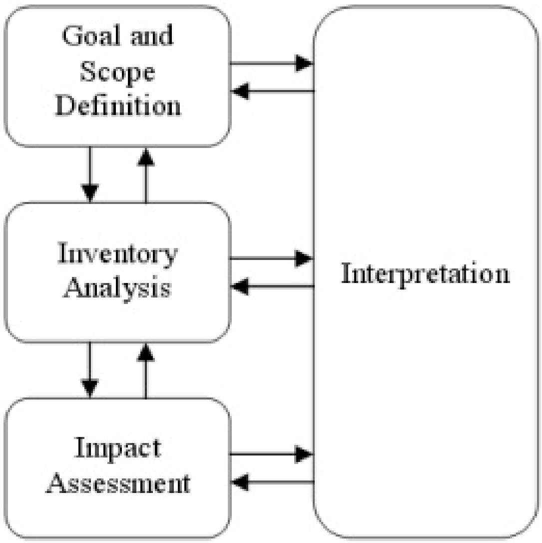

Figure 15: Four stages of life cycle assessment (according to Grösser, 2017, p. 99)

As visualised in Figure 15, the life cycle assessment according to ISO 14044:2018 is conducted in four stages; the most critical characteristics of every stage are presented as follows:

i. **The first stage** is called Goal and Scope definition, where, as their name suggests, the goal of the study is defined and system boundaries are set. It can be executed as 'Cradle-to-Grave' or 'Cradle-to-Cradle' version; however, in reality it is a compromise between feasibility and integrity. (Bretzke, 2014, p. 137) Furthermore, the functional unit is chosen within this step; it is used to quantify the profit of a production system and is classified as a reference value for the input and output analyses (Oberösterreichische Zukunfts Akademie, 2014, p. 3).

ii. **The second stage** includes the inventory analysis within all data that cross the system boundary being collected. The inputs and outputs of the system are presented in the form of a balance sheet. This balance sheet includes not only the used energy and raw materials but also the emissions released into the atmosphere and water. (Grösser, 2017, p. 98 ff.)

iii. **The third stage** is named Impact Assessment and works with the data from the inventory analysis. Life Cycle Impact Assessment is the term given to the data that are transformed into impacts on various human and terrestrial ecosystems. One possibility for illustrating this impact is the carbon footprint calculation, yet several other methods exist to indicate this, such as eutrophication, acidification, or photochemical ozone formation. (Grösser, 2017, p. 98 ff.)

iv. **The fourth and last stage** is the interpretation and summarisation of the results with the generated data from the three previous stages. The outcome of this stage is the input for decision-making in an environmentally friendly manner and leads to changes. Pollution-intensive processes are figured out, and with iterative steps, solutions are implemented. (Grösser, 2017, p. 98 ff.)

4.2.3. ISO 14064:2018

ISO 14064:2018 is responsible for definitions of the requirements of an organisation’s GHG inventory; this includes design, development, management, reporting and verification. The norm is split into three parts, each of which is related to another technical focus. As stated in ISO (2018, p. VII) the parts are listed below:

i. **Part 1** is titled ‘Specification with guidance at the organisation level for quantification and reporting of greenhouse gas emissions and removals’. In this part the GHG inventories of organisations or corporations are collected, consolidated, and quantified.

ii. **Part 2** deals with ‘Specification with guidance at the project level for quantification and reporting of greenhouse gas emissions and removal enhancements’ and includes the requirements for planning, identifying, and selecting GHG projects as well as the abovementioned activities.

iii. **Part 3** is named ‘Specification with guidance for the validation and verification of greenhouse gas assertions’, in which the verification of a GHG statement is implemented.

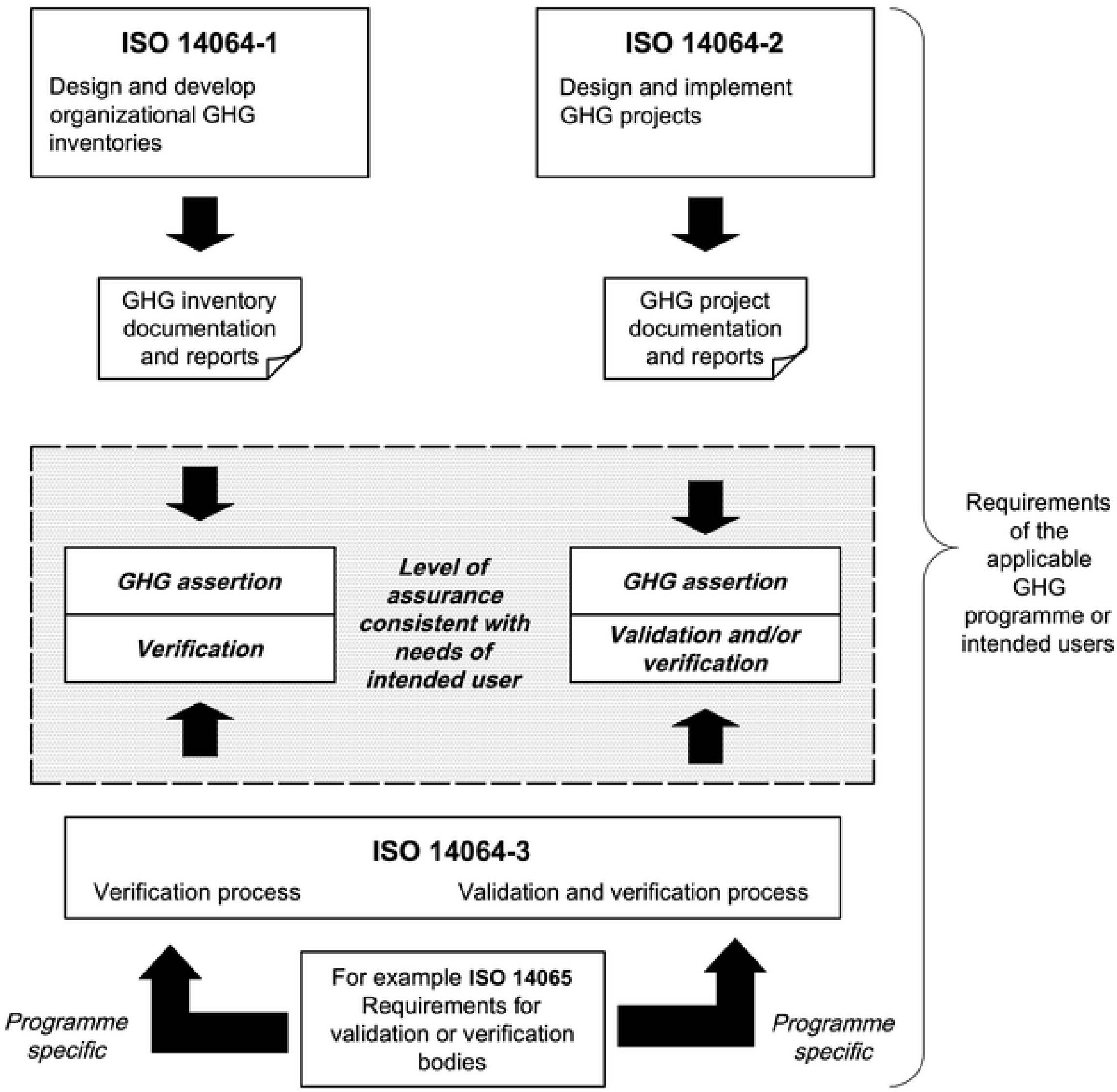

Figure 16: ISO 14064 (according to ISO, 2018, accessed on: 04.03.2019)

Wintergreen and Delaney (2007, p. 1 ff.) provided three key aspects for the successful analysis of an organisation:

i. Setting inventory boundaries

Two types of boundaries exist, namely organisational boundaries and operational boundaries. Organisational boundaries define which facilities are part of the organisation, and this can be defined as control or as equity share. The control approach consists of financial or operational policies through which the organisation have control over GHG emissions, whereas the equity share approach comes from facilities with some equity interest. Operational boundaries clarify which operational activities are included, independent from direct or indirect emissions.

ii. Quantifying GHGs

In this step the collection of required data within the system boundary is usual and the identification of accurate emission factors is done. The identification of the necessary data is performed with the same method as used by the Greenhouse Gas Protocol (see subsection 4.2.1). The emissions are also summarised separately by direct and indirect sources.

iii. Reporting GHGs

The report should include the boundaries and calculated emissions as well as explain the inventory components.

In sum, not only different variants of carbon footprints exist but also various methods of standards for calculation. The most crucial factor that all methods possess is the definition of system boundaries and the level of abstraction. Only a clear description of the contributing factors enables a transparent calculation and leads to sustained success. In contrast, the decision on which standard the calculation is based on, is not so crucial because they mesh.

5. Object of Investigation

As mentioned in the title of the thesis, a case study analysis of environmental impact is conducted in cooperation with Pankl Racing Systems AG. In this chapter, relevant facts and data for calculating the carbon footprint of the investigated company are listed. Additionally, the actual environmental management system is demonstrated and forms the foundation for further assumptions.

5.1. Company Description

Pankl Racing Systems AG has its headquater in Kapfenberg, Austria. It is a global acting company that develops, maintains, and distributes in the hi-tech field for dynamic components applied in the worldwide niche markets of motor racing, luxury automobiles, and the aviation industry. The goal of the company is to be the leading innovator within all its business units and corporate fields when new products and materials are launched. Its guiding principles throughout all areas are high tech, high speed, and high quality. (Pankl Racing Systems AG, 2019a, accessed on: 03.04.2019)

The traditional Austrian company has subsidiary locations worldwide, including in the USA, Germany, UK, Slovakia, and Japan. Together with the management of Pankl, the object of investigation for this thesis is limited strictly to the Austrian plants. This restriction is absolutely necessary on the basis of different legislation outside of Austria, and because the currently available data are more comprehensive and more accurate at Pankl's homebase. Based on this, all presented data in Table 5 and the following calculations include only data generated within Austria. (Pankl Racing Systems AG, 2019a, accessed on: 03.04.2019)

Pankl was founded in 1985 by Gerold Pankl, and currently, the company structure is split into three main divisions: 'Racing', 'Aerospace', and 'High Performance'. The division 'Racing' dates from the founder of the company and is at present subdivided into 'Engine' and 'Drivetrain' applications. The 'Aerospace' division was implemented in 1994 and the 'High Performance' sector has been successfully expanded over the last few years. The latter is also subdivided into two sections, the eponymous 'High Performance' and 'Forging' subdivisions. (Pankl Racing Systems AG, 2019a, accessed on: 03.04.2019)

Figure 17 illustrates the above mentioned information with some examples of the individual produced parts, but the subdivision 'Forging' is not explicit mentioned.

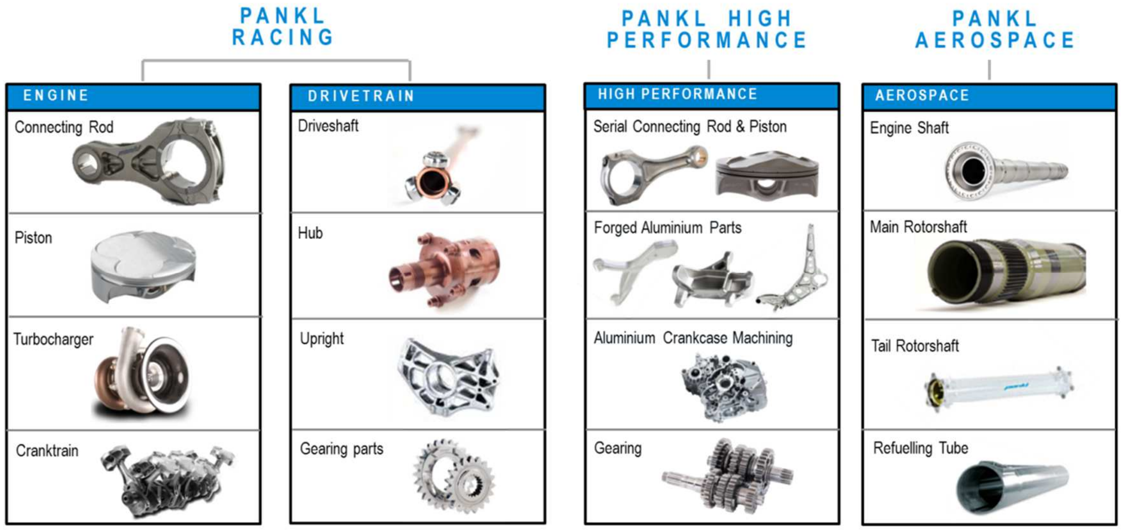

Figure 17: Pankl Divisional Organisation (according to Pankl Racing Systems AG, 2019a, accessed on:03.04.2019)

A divisional organisation is characterised by the structure of the company being related to products or divisions. This form of organisation usually has a diversified product range, as is the case with Pankl. The individual divisions are self-responsible for business operations and only underlie top management in strategic decisions. (Thommen, et al., 2018, p. 342) Table 4 compares the advantages and disadvantages of this form of organisation to enable a common understanding.

Advantages	Disadvantages
• Distinct responsibilities • High flexibility • Managerial specialisation • Easily recognisable product success • Discharge of top management	• Competition between divisions • Duplication of activities and resources • High personal and management requirements • Short-term thinking can occur

Table 4: Divisional Organisation (according to Thommen, 2018, p. 342)

To comprehend the strategic position of the company, Figure 18 provides an overview. Generally speaking, different methods exist for companies to achieve a competitive advantage, which can be separated using Porter's generic strategies. According to Porter, three main business strategies exist: cost leadership, differentiation, and focus. Cost leadership is successful in having the lowest prices in the target market, whereas differentiation focuses on non-price sensitive, specific customers' needs, which often come in the form of image or brands. The focus strategy gains an advantage through product innovation and specialising in selected market segments. (Goldman & Nieuwenhuizen, 2006, p. 75 ff)

Transferring these strategies to the company Pankl and considering the abovementioned guiding principles, it is unambiguous that Pankl is reaching a competitive advantage with its policy focus.

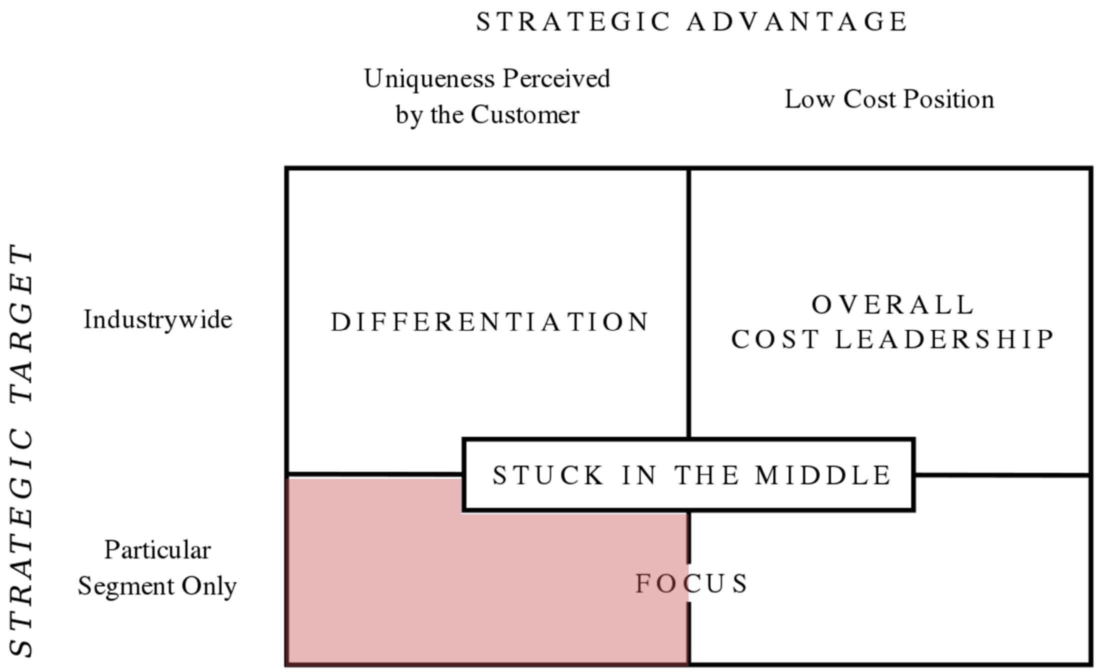

Figure 18: Porter's generic strategies (according to Wikipedia, 2019 modified, accessed on: 04.04.2019)

As previously mentioned, environmentally friendly production is gaining importance among customers. This is why it is so important for the company, especially with the chosen strategic position, to develop a sustainable management and to get known as a green company.

After presenting the company's main products and organisational structure, Table 5 lists the hard facts of the company. The data, which will be used for upcoming calculations, are divided into the abovementioned divisions and generated for the calendar year 2018. A difference between the sum of the divisions and total amount can occur through unclear allocations of the object. These values are crucial not only for conveying the size of the company but also as important reference values for later in this thesis.

Division / Category	ENGINE	DRIVE	HIGH PER	FORGING	AERO	Total
Operating performance [Tsd€]	61,379	30,858	12,982	15,523	13,668	134,412
Number of working hours [h]	662,968	244,030	85,101	95,432	69,144	1,156,675
Number of employees[#]	374	225	114	96	102	1036
Shop floor area [m^2]	9,648	12,588	9,206	4,267	2,940	38,649

Table 5: Hard facts 2018 (according to company internal data; Pankl Racing Systems AG, 2019b, accessed on: 03.04.2019)

As outlined in Table 5, the size of the individual divisions is varying significantly. Therefore a separate consideration and assignment of impact factors is inevitable.

Next, Pankl is analysed regarding its structure, strategy, and business data. The following section examine Pankl’s existing and approved management system.

5.2. Environmental Management at Pankl

Pankl has its own environmental management team for every division, this team is a part of Pankl's quality management department. The company has already an implemeted environmental management system, they are using ISO 14001:2015 (see section 3.2). The main advantage of ISO 14001:2015 over EMAS (see section 3.3) is that the certification has a worldwide legal force, whereas EMAS is only valid in Europe. Based on the fact that Pankl has locations and customers worldwide, this is a critical characteristic. Presently, the environmental management system is implemented successfully in the company and receives necessary support from top management and other responsible employees.

As mentioned in the description of ISO 14001:2015, a continuous improvement of the process is essential. This thesis can be seen and used as a next step within this planned cycle. Although the system is proven and works successfully, the current situation causes operational problems for the organisation. One significant disadvantage is handling the enormous amount of data and keeping it actual, which costs much extra effort for the responsible team of employees. Furthermore, and referring to subsection 5.1, it is challenging to implement one standard of data maintenance and presentation of results throughout all divisions at Pankl.

Currently, the environmental management team works primarily with two self-generated Microsoft Excel files. These sheets are used as the foundation for formulating the general environmental targets for the upcoming quarters of a year.

The first Excel document is internally called 'Umweltcockpit', which basically collects data from other Excel sheets and presents the environmental performance of each division. The collected data, which are completed periodically at every division, consist of: electricity, gas, stored compressed air through the measurement of leakages, waste products, and metal recycling. At some divisions, an input–output analysis of material has been started but has not yet been rolled out across the whole company throughout all divisions. An extract of this Excel file is shown in the Appendix. The general problem with this data sheet is that the continuous data maintenance is time-consuming and failures can occur because of too many data sources and subsequent duplicate datasets.

The second file is called 'Umweltaspekte Matrix' and an example is provided in the Appendix (page 8). It uses the risk priority number (RPN) in a modified manner to demonstrate which operational part of the company has the most significant need for actions to reduce the environmental impact. The RPN is not calculated as taught in the literature, by Perry & Bacon (2006; p. 263 ff.), of a failure mode and effects analysis (FMEA) with ratings of the following three questions from 1–10:

- The likelihood that a failure occurs
- The likelihood that a failure will not be detected
- The amount of harm or damage the failure mode may cause to a person or item of equipment

$$RPN = Occurence * Detection * Severty \leq 1000$$

Equation 1: RPN (according to Perry & Bacon, 2006, p. 263 ff.)

In the style of the RPN mentioned in Equation 1, Pankl modified the object of investigation. The RPN of the 'Umweltaspektematrix' is calculated by rating every individual process following aspects 1–4. The rating is not based on concrete values based on the processes, it is executed by an experienced employee. The multiplication of these factors results in the RPN of Pankl's environmental aspects.

- UPR: The number of resources that are used, classified into energy sources and raw materials
- UPE: The amount of emissions that are released into water, the atmosphere, and the immediate surroundings
- UPA: The amount of waste produced
- UPBV: Whether binding commitments exist for the process step

$$RPN = UPR * UPE * UPA * UPBV \leq 256$$

Equation 2: RPN – Environmental Management by Pankl (according to company internal data)

A single result greater than 100 leads to a closer consideration of the subject and forms the central focus for the environmental target definition. The problem with this methodological method is that the rating is subjective without being based on datasets and no meaningful comparison throughout the divisions is possible.

The two presented Excel sheets form the initial situation of this thesis. The included datasets are used for pursuing calculations, and the files are supplemented—or rather reorganised—in the course of this thesis. In the end the abovementioned problems should no longer be relevant. Additionally, it is aimed at implementing the subsequent calculated footprint as a strategic tool in the environmental management system.

6. Calculation

This chapter deals with the calculation of the CCF of Pankl. The structure is inspired by the life cycle assessment of products, processes or services according to ISO 14044:2018, but transferred from the product level to company observations. The consideration starts with the scope definition and clarifies the essential assumptions for a clear presentation. Subsequently, the inventory analysis, which represents the most critical material and energy flows of the whole company, is analysed. The central part of this chapter is calculating the CCF, which is conducted using the GHG Protocol. The decision not to use ISO 14064:2018 is based on the fact that the GHG Protocol is the original source, whereas ISO 14064:2018 rests upon the other. To fulfil the framework, the interpretation of the results ends the chapter.

6.1. Scope Definition and Assumptions

The scope of the environmental impact analysis includes all activities within Pankl as well as all activities related to or controlled by the company. The following list provides an overview of what is taken into consideration within the system by utilising the steps of the life cycle assessment; general assumptions of the stages are mentioned. Furthermore it is a top-down approach for data generation chosen, because as mentioned in section 4.2, it is more time efficient and the level of abstraction can be modified in further steps.

i. Supply chain

Pankl is in most cases not responsible for the selection of suppliers and materials, predominant regulations are prescribed by customers. Moreover, based on the niche market orientation, the products or rather the materials must fulfil the highest technical and quality-related standards. A modification in the material selection is fundamental and not possible without changing the finished product’s characteristics. Therefore, the supply chain is not part of the consideration.

ii. Delivery

Deliveries of raw materials or other goods from suppliers to the company are in most cases organised and controlled by Pankl’s subsuppliers. As a result, they are not in the area of scope and responsibility of Pankl, and thus are not included in the calculation.

iii. Manufacturing

The manufacturing process is not subdivided into individual products or single processes; the whole company Pankl is seen as a so-called ‘black box’, only subdivided into the aforementioned divisions. This decision is made to generate an overview about the whole company. Moreover, the variety of products and processes does not permit a consideration of every individual, and for an extrapolation with representative values the products are too diverse.

To ensure that the majority of the influencing factors are still covered without creating senseless quantity of data, only the three most used raw materials are part of the scope for every division.

For auxiliary materials, lubricants, or oils and gases, only the main groups are mentioned and no separate classification is used because otherwise the variety would be too high. With these adaptations, the most significant factors affecting the result are incorporated into the calculation

As mentioned in subsection 4.2.2, defining the unit is crucial, and with this supposition the comparableness between the mass flows can be guaranteed; this makes the analysis independent of a specific product. As units for the input of raw materials, auxiliary materials, lubricants, or oils and gases, as well as the outputs from finished goods, waste, or emissions are defined as mass[t], whereas the functional unit for energy sources is energy [kWh].

Some processes are outsourced from Pankl, but no specific data about the production processes are available for such external work. Moreover, the company has no supervision over their external processes or environmental performance; therefore, it is not part of the scope. Nevertheless, the transportation of goods to and from the partner company is part of the inspection because this is under the responsibility of Pankl.

iv. Delivery

As opposed to the delivery of raw materials, that of finished goods from the company to the customer are organised by Pankl. Because of this data, it is also part of the impact analysis.

v. Product use and end of life treatment/waste

The company has no information available about the customers' product use because it produces components for a product with a huge number of individual parts. Therefore, an assignment to each single component is not possible. Furthermore, because of the high-end clientele in different market segments no data generation is possible for Pankl. Additionally the costumers have partially a considerable degree of confidentiality.

As mentioned, no data are available about product use, and consequently no information exists about the end-life treatment of Pankl products. The situation for the waste, which is generated during the production processes, is different. The energy sources used for end-life treatment of the company's internal waste are part of the consideration. This is indeed part of the calculation because the company can influence the produced amount of waste and method of disposal.

As can be seen, the individual definition of the scope is a crucial step for enabling a transparent further calculation. At this point, only the general assumptions along the value chain are mentioned, and necessary adoptions for the individual categories are listed separately.

6.2. Inventory Analysis

As explained in subsection 4.2.2, a vital step for ISO 14044:2018 is an inventory analysis. It is used to generate an overview of the amount of inputs and outputs that cross the defined system boundary. Figure 19 presents a schematic of all material and energy flows applied to Pankl, illustrated as a 'black box'.

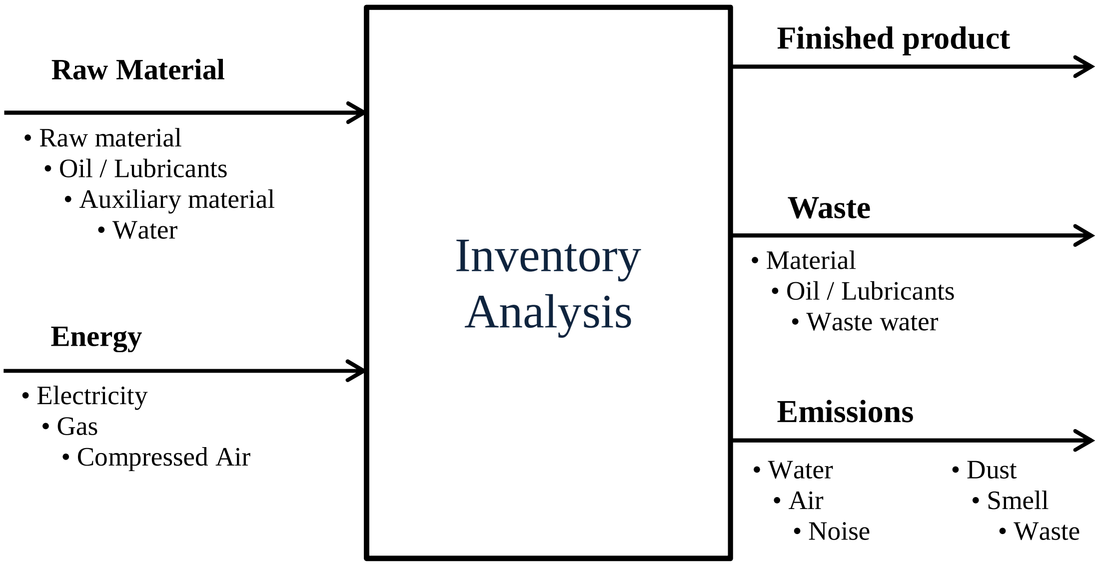

Figure 19: Inventory Analysis (own illustration)

The applied model represents the results of the inventory analysis in Table 7. For a meaningful comparison between the amounts of inputs and outputs, some further assumptions must be set.

i. The input data of raw materials and energy sources can be extracted from the purchasing department using invoices, direct or indirect meter readings, or other delivery documents, whereas the output data for finished products are not easy to generate.
The first problem with data generation of the finished products is that only the weight of the whole product is stored and no separation into different materials is possible, or integrated bought-in components are included in this value. The second problem is that the waste is not sorted by a single material specification but is classified into waste numbers and recyclable metals and not further characterised. Notwithstanding the weight of the waste is known and can be extracted from the waste invoices.
Based on this, the product weight is calculated using a back calculation from the generated waste and input material.

$$Finished\ products\ [t] = Raw\ Material\ [t] - Waste\ [t]$$

Equation 3: Weight of finished products

This approach has one main disadvantage: the value of finished products can only be approximated, and the classification into single materials gets lost because of the missing degree of detail from the waste data.

ii. The approach shown in point (i) cannot be adopted for auxiliary materials, oil/lubricants, and gases because the waste products are diluted with water or consumed during the process. Based on the variety of processes, the amount of clean or filtered water cannot be completely tracked. Therefore, the contaminated water is deposed of as acid waste.

iii. It is assumed that input process water is as abundant as output water; losses through evaporation or other manufacturing processes are classified as negligible.

iv. Table 7 includes only one part of emissions, namely air pollution. This value is comprised of emissions directly produced by Pankl, which are defined as Scope 1 of the Carbon Footprint Calculation (see subsection 4.2.1). The mentioned emissions are anticipated from subsection 6.3.1 and not further explained at this point. Because no data are available for the other forms of emissions, an alternative approach has to be chosen. Instead of data, significant questions about the emissions (noise, surface shaking, dust, smell and waste heat) should provide an overview of this topic. Another reason for this procedure is that different locations of Pankl plants have different critical values. The divisions located in Kapfenberg are part of an industrial area, where (for example) noise and surface shaking are smaller problems compared to Bruck an der Mur, where the company is in a residential neighbourhood.
This study defined the following three questions to replace the absolute values. These question are answered for every emission category by an expert within the company.

- Are there any complaints or incidents that are a result of the emissions?
- Are there any preventative measures set?
- Does the company have a possible direct influence on the produced emissions?

A classification system where the categories are defined in an explicit manner ensures that the assessment is based on facts. The limitations of this approach is that it cannot be included in the inventory analysis because no values in the form of functional units are available.

INPUT (2018)						
Division / Type	ENGINE	DRIVE	HIGH PER	FORGING	AERO	Total
Aluminium	5	23	2	1817	131	1978
Steel	487	181	694		95	1457
Titan	112	3	1		4	120
Graphite				27		27
Copper				1		1
Total raw materials [t]	**603**	**207**	**697**	**1844**	**230**	**3582**
Auxiliary materials	1.2	0.3	81.1			82.7
Oil / Lubricants	32.9	9.3	16,6	0.3	2.0	61.1
Gases	63.5	0,2	268.8	1,4	0.1	334.0
Total acids [t]	**97.6**	**9.8**	**366.5**	**1.7**	**2.1**	**477.7**
Compressed air	963,832	104,450	307,941	180,000	44,764	1,600,987
Electricity	6,794,578	3,514,043	4,949,240	4,243,663	1,446,192	20,947,716
Gas	860,055	559,347	26,6845	3,466,564	239,720	5,392,531
Total electricity [kWh]	**8,618,465**	**4,177,840**	**5,524,026**	**7,890,227**	**1,730,676**	**27,941,234**
Total water [m³]	**1202**	**1573**	**3867**	**3656**	**674**	**3656**

Table 6: Inventory Analysis – Input (according to company internal data)

OUTPUT (2018)						
Division / Type	ENGINE	DRIVE	HIGH PER	FORGING	AERO	Total
Recycling	2	1	3	374	4	384
Waste materials	20	9	14	28	4	75
Total waste materials [t]	**23**	**11**	**17**	**402**	**8**	**459**
Total waste acids [t]	**71**	**103**	**50**	**34**	**44**	**302**
Products [t]	**580**	**196**	**680**	**1442**	**222**	**3123**
Total wastewater [m³]	**1202**	**1573**	**3867**	**3656**	**674**	**3656**
Emission [t CO_2-equ]	**209**	**136**	**65**	**843**	**58**	**1311**

Table 7: Inventory Analysis - Output (according to company internal data)

Haven taken all these factors into account, the inputs and outputs of the company Pankl are from now on clear. The interpretation of the results is described in section 6.4.1, but the way for the CCF calculation is levelled.

6.3. Carbon Footprint Calculation

The following subchapters demonstrate in detail the calculation of the carbon footprint using the Greenhouse Gas Protocol method (see subsection 4.2.1). The calculation is split into three scopes, and the individual values are presented using tables. The units defined as tons [t] for emissions remain unchanged, but the input units can vary because of different forms of data generation. All used units and conversion factors are explicitly mentioned in the tables to ensure transparent calculations.

The CO_2-equ values used for the calculation are predominant according to the GHG calculator of Umweltbundesamt Austria (Umweltbundesamt, 2017, accessed on: 28.01.2019) or the web portal ProBas, which is part of Umweltbundesamt Germany (Umweltbundesamt, 2015, accessed on: 28.01.2019). If another source is used, the appropriate reference is mentioned separately. A specific focus lies on the selection of the CO_2-equ values on public sources so as to not be influenced by the private industry.

6.3.1. Scope 1

As mentioned in the description of the GHG Protocol, Scope 1 is used to report the company-owned or directly controlled sources. The following preparation of specifications must be done to clarify the calculated values.

i. Gas

The data for the used gas can be extracted from the invoices of the gas supplier. These values are given in [kWh], but the calculation of CO_2-equ is according to Umweltbundesamt (2017, accessed on: 28.01.2019) executed with burned volume [m³]. Based on this, a recalculation must be conducted. The conversion factor from energy [kWh] into volume [m³], suitable with the market area ost, is the volumetric energy density with a conversion ratio according to E-Control (2019, accessed on: 04.08.218) of 11,30 kWh/m³. The values used for the calculation in Table 8 are hence converted into [m³].

$$[\mathrm{m}^3] = \frac{[\mathrm{kWh}]}{11{,}3}$$

Equation 4: Conversion factor [kWh] into [m³] (according to E-Control, 2019, accessed on: 04.04.2019)

ii. Company cars

Pankl has a carpool with 34 cars. The CO_2-equ are based on the manufacturer specifications of the individual cars, and are given in passenger kilometre (Pkm). In Table 8, the average of these values is stated, but the calculation is executed with the exact values. Furthermore, the information about annually driven kilometres is gathered from the leasing contract partner, which is based on mileage status. The cars are available for the whole company and divisions. Therefore, a specific assignment into divisions is not possible. Nevertheless, for generating an overall picture, a separation is performed using the employee numbers for each division (see Table 5).

Scope 1	CO_2-equ	ENGINE [t]	DRIVE [t]	HIGH PER [t]	FORGING [t]	AERO [t]	Total [t]
Gas	2748 $[\frac{g}{m^3}]$	209.15	136.03	64.89	843.02	58.30	1311.39
Carpool	130,2 $[\frac{g}{Pkm}]$	70.04	42.14	21.35	17.98	19.10	170.61
Total scope 1		**279.20**	**178.16**	**86.24**	**861.00**	**77.40**	**1482.00**

Table 8: Scope 1 (according to company internal data; Umweltbundesamt, 2017, accessed on: 28.01.2019)

6.3.2. Scope 2

The generation of purchased electricity is part of scope 2, this includes for the consideration of Pankl the used electricity and compressed air. Given that compressed air is part of the overall used electricity, these values are subtracted to avoid double counting.

i. Electricity

Electricity generation is conducted by the so-called ‘energy generation Austria’. The specific CO_2-equ values therefore are used. The quantity of purchased electricity can be read from the invoices of the electricity supplier.

ii. Compressed air

The used compressed air is considered separately to calculate the additional environmental impact. The amount of used electricity can be counted in the form of meter readings. The CO_2-equ value for compressed air is given in the list of (Umweltbundesamt, 2015) in units of [g/m³]. Therefore, Equation 4 has to be used to convert [kWh] into [m³], because the meter readings of compressed air are given in [kWh]. The mentioned values have already been transferred into the correct unit. Consider that declared CO_2-equ for compressed air does not only include the used electricity, but also the upstream chain and the average use on lubricating oils. Therefore, is an exact assignment to scope 2 not possible, but a disaggregation unnecessary complicate the overall result.

Scope 2	CO_2-equ	ENGINE [t]	DRIVE [t]	HIGH PER [t]	FORGING [t]	AERO [t]	Total [t]
Compressed air	75.3 $[\frac{g}{m^3}]$	820.1	88.8	262.0	153.1	38.0	1362.2
Electricity	248 $[\frac{g}{kWh}]$	1685.0	871.4	1227.4	1052.4	358.6	5195.0
Total scope 2		**2505.1**	**960.3**	**1489.4**	**1205.5**	**396.7**	**6557.3**

Table 9: Scope 2 (according to company internal data; Umweltbundesamt, 2017, accessed on: 28.01.2019; Umweltbundesamt, 2015, accessed on 28.01.2019)

6.3.3. Scope 3

Because the system boundary only includes company-owned or self-controlled processes, not all categories of scope 3 (named in subsection 4.2.1) are included in the calculation. Additionally, it is also not further subdivided into upstreaming and downstreaming activities as mentioned in the Greenhouse Gas Protocol because the system boundary excludes most activities.

i. Business trips

The data for business trips can be divided into two sections: business trips driven with company cars and international business trips by air. The first type are part of scope 1 because driven kilometres are included in the consideration of the company-owned cars, and at this point they are not counted for a second time. For the second type, the data generation is more complex. Every employee who going on a business trip has his or her own frequent flyer programme (Pankl uses ‘miles and more’) account. On this account, all relevant data are stored but only the individual employee has access to it. That is why the concerned employees are asked for their personal flight data. As a result, the data of business trips are not fully completed, but it is assumed that the majority are covered following the 80/20 rule. Because an exact assignment into divisions is not possible within this method of data generation, it is performed according to the number of employees.

Means of Transport	CO_2-equ $[\frac{g}{Pkm}]$	Engine [t]	DRIVE [t]	HIGH PER [t]	FORGING [t]	AERO [t]	Total [t]
Plane	**416.8**	**158.0**	**95.0**	**48.1**	**40.5**	**43.1**	**384.8**

Table 10: Business trips (according to company internal data, Umweltbundesamt, 2018, accessed on: 28.01.2019)

ii. Individual transport

Data acquisition according to the individual mode of transport of employees on their daily commute to work is conducted using an employee survey. This topic is added as an element of an Austria-wide employee survey of Pankl conducted in late 2018 to be used for the present thesis. An external company called Medicon is responsible for the execution of the survey, but the precise questioning and evaluation is an integral part of this thesis.

For the generation of specific data about the age and fuel type of the private car, carpooling, and means of transport, a quantitative formulation of questions with multiple choice answers is chosen, whereas the driving distance are an open question with a simple, numeric response possibility. The specific formulation of the question can be found in the Appendix (page 9).

The survey is sent to 1036 employees, of which 472 are adequately returned. Because the return rate is approximately 45.5%, exploration of the total number of employees is permitted.

The question concerning the means of transport resulted in a percentage distribution (Figure 20). As expected, the most significant mode of transport is the car which covers 92 %. of Only 14.63% from the car users are driving a carpool together with other employees regularly. In the calculation, a worst case scenario is assumed, which means that in one carpool there are only two people. Furthermore, considering vacation, weekend, and legal holidays, the total number of working days is set to 227 in 2018.

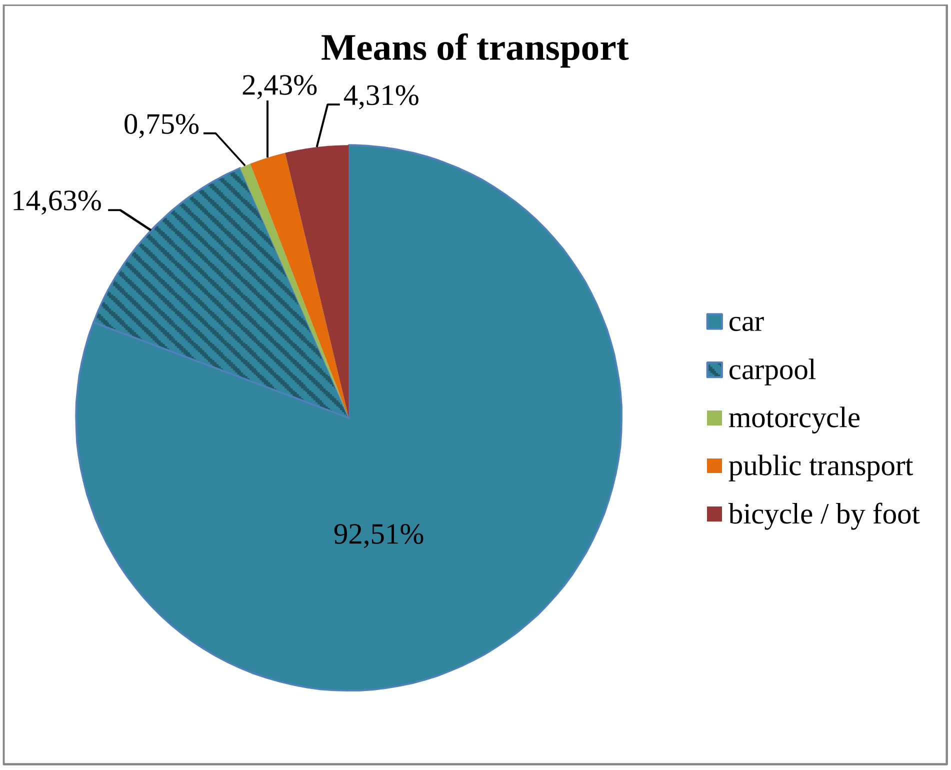

Figure 20: Means of transport (own illustration according to company internal data)

For a more useful overview, cars are divided into petrol and diesel engines and further into older cars (built before 2009) and younger cars (built after 2009). This split is useful because a radical change in CO_2-equ values is mentioned in this period. The equivalents for Table 11 are generated as the mean value for new licensed cars in the time spans 2000–2009 and 2010–2016, they are given in passenger-kilometre [Pkm]. (Bundesministerium Nachhaltigkeit und Tourismus, 2018, p. 19 f.)

Means of transport		Distribution	CO_2-equ $[\frac{g}{Pkm}]$	km per direction	km per year	Total [t]
Car	petrol > 2009	17.80%	130.7	4399.8	1,997,510.7	1693.1
	petrol $\leq$ 2009	13.98%	165.4	3251.5	1,476,179.8	
	diesel > 2009	40.68%	133.9	12,716.9	5,773,462.2	
	diesel $\leq$ 2009	27.33%	160.6	5688.6	2,582,621.4	
Bus			52.51	908.1	412,258.1	21.65
Motorcycle			77	128.3	58,233.8	4.5
Total individual transport				**27,093.1**	**12,300,266.1**	**1719.2**

Table 11: Individual transport (according to company internal data; Bundesministerium Nachhaltigkeit und Tourismus, 2018, p. 19 f.)

iii. Waste

Pankl commissions the contracted company Saubermacher for waste disposal. The CO_2-equ emissions for this downstream process are specially calculated for Pankl and utilises waste numbers and their related weights. A detailed breakdown of the calculation including the relevant CO_2-equ values is provided in the Appendix. Generally, the emission calculation is according to the assumption of how much energy in [kWh] is required to destroy one ton of the specific material. Saubermacher mentions that if waste is used for material or thermal recycling, the saved energy input in comparison to raw material extraction is calculated and can be seen as saved CO_2-equ.

Waste	Engine [t]	DRIVE [t]	HIGH PER [t]	FORGING [t]	AERO [t]	Total [t]
Total waste	**80.3**	**53.9**	**53.8**	**34.5**	**77.0**	**299.5**

Table 12: Total waste (according to company internal data)

iv. Delivery

The delivery aspect includes the transportation distance and method from the company to the customer as well as to the external services or returns to the company. According to the geographic location of the customer or business partner, the delivery is made by truck, train, or plane. As a general policy, deliveries within Central Europe are by truck, whereas overseas exports are by plane. Transportation by ship is not possible because of the enormous time delay between shipping and receiving goods at the customer-end.

The value of CO_2-equ is given in tonne-kilometre [Tkm], which means that calculation considers the weight of the sent products, but not every delivery weighs exactly one ton. Furthermore, the occupancy rate of the trucks is unknown, and the classification of the truck considers that age, size, and technical data are unknown factors; however, it is assumed that a mean value for heavy international transports can be applied. Therefore, the value is an approximation, because a closer observation of logistical transport management is not expedient. Table 13 is divided into the different means of transport to visualise their impacts.

Means of Transport	CO_2-eq $[\frac{g}{Tkm}]$	Engine [t]	DRIVE [t]	HIGH PER [t]	FORGING [t]	AERO [t]	Total [t]
Plane	531	4233.7	738.1	27.1		335.1	5333.9
Truck	86.8	370.4	71.4	14.4	2429.8	19.4	2905.4
Train	5.5		1.1				1.1
Total delivery		**4604.0**	**810.7**	**41.5**	**2429.8**	**354.4**	**8240.4**

Table 13: Delivery (according to company internal data; Umweltbundesamt, 2018, accessed on 28.01.2019; Öko-Institut e.V., 2011, accessed on: 23.04.2019)

The summarisation of all these aspects mentioned from point (i.) to point (iv.) results in scope 3; Table 13 provides an overview.

Scope 3	unit	ENGINE [t]	DRIVE [t]	HIGH PER [t]	FORGING [t]	AERO [t]	Total [t]
Business trips	$[\frac{g}{Pkm}]$	158.0	95.0	48.1	40.5	43.1	384.8
Individual transport	$[\frac{g}{Pkm}]$	705.8	424.6	215.1	181.2	192.5	1719.2
Delivery	$[\frac{g}{Tkm}]$	4604.0	810.7	41.5	2429.8	354.4	8240.4
Waste	[t]	80.3	53.9	53.8	34.5	77.0	299.5
Total scope 3		**5548.0**	**1384.2**	**358.6**	**2686.0**	**667.0**	**10643.9**

Table 14: Scope 3 (according to company internal data)

Having considered all these factors, the overall CCF Pankl is calculated for the defined system boundary. A modification in the range of consideration led to a change in the results. The engaged assumptions are only valid for the investigated company and cannot be generalised. A visualisation and summary of the scopes are mentioned in subsection 6.4.2.

6.4. Interpretation

This chapter summarises the inventory analysis and carbon footprint calculation. The results are visualised with different methodical approaches and an interpretation of the results rounds out the calculation, as mentioned in the theory of this thesis.

6.4.1. Interpretation - Inventory Analysis

With the data generated from the inventory analysis, the foundation for the carbon footprint calculation is set. These data offers the possibility to calculate the material efficiency. To reach a high material efficiency is not only a key environmental aspect but also an important economic factor. The formula for calculating the material efficiency is directly connected between material input and output.

$$Material\ efficiency = \frac{Output\ Finished\ Products}{Input\ Raw\ Material} * 100$$

Equation 5: Material efficiency (according to Engelfried, 2012, p. 20)

As Figure 21 shows, a high material efficiency exists, but this consideration only examines the production efficiency and does not incorporate potential savings in the design of the products.

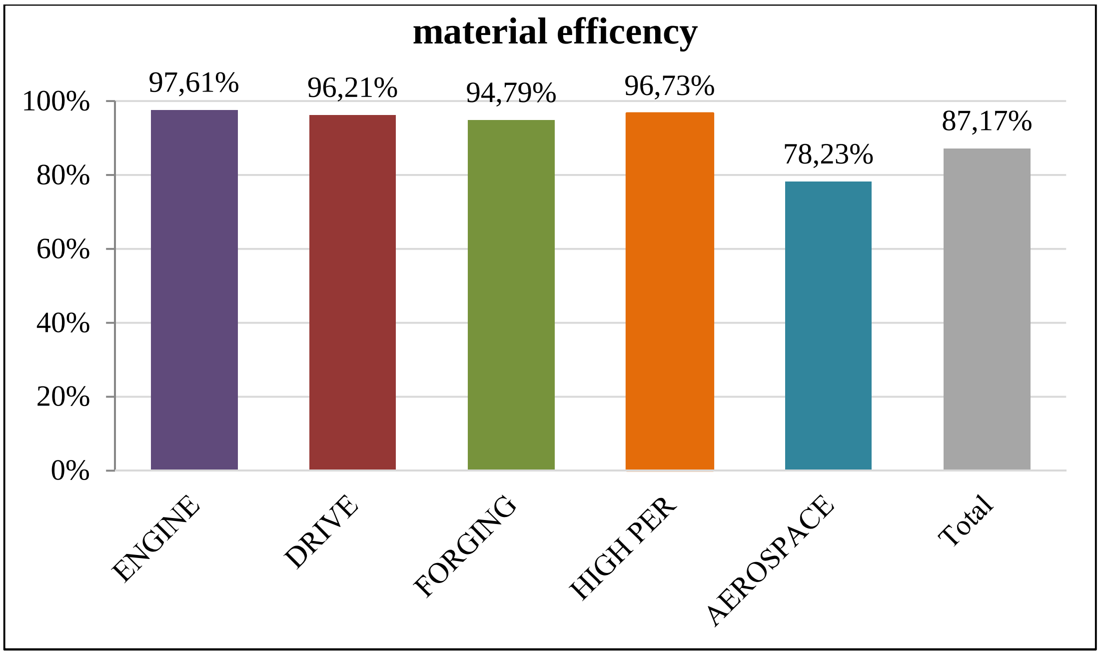

Figure 21: Material efficiency (own illustration according to company internal data)

The material efficiency is in most divisions significantly above 90%, only the sector Aerospace does not reach this value. Based on the fact that the analysis of causes for this low value goes beyond the bounds of this thesis, it is not further examined.

To calculating the efficiency of auxiliary materials, oils/lubricants, and gases is not possible because these goods are diluted with water, and therefore, their value would not be meaningful.

6.4.2. Interpretation - Carbon Footprint

Gathering all categories together, the sum of the scopes result in the total CCF of the company. The individual scopes are listed again in Table 15 to provide an enhanced visualisation of total amounts.

Scope	ENGINE [t]	DRIVE [t]	HIGH PER [t]	FORGING [t]	AERO [t]	Total [t]
Scope 1	279.2	178.2	86.2	861.0	77.4	1482.0
Scope 2	2505.1	960.3	1489.4	1205.5	396.7	6557.3
Scope 3	5548.0	1384.2	358.6	2686.0	667.0	10,643.9
Total CO_2-equ	**8332.4**	**2522.7**	**1934.2**	**4752.6**	**1141.2**	**18,683.2**

Table 15: Overall carbon footprint (according to company internal data)

Figure 22 illustrates the orders of magnitude of the individual scopes, or rather categories of the scopes. The most significant component in the calculation of the carbon footprint according to the Greenhouse Gas Protocol is Scope 3, which is because of its wide range of consideration. Against the expectations in a manufacturing enterprise the category delivery is identified as the main contributor to the GHG emissions and covers 44.1% of the overall amount. This category is followed by the electricity with a quantity of 27.8% of GHG emissions translated into CO_2-equ.

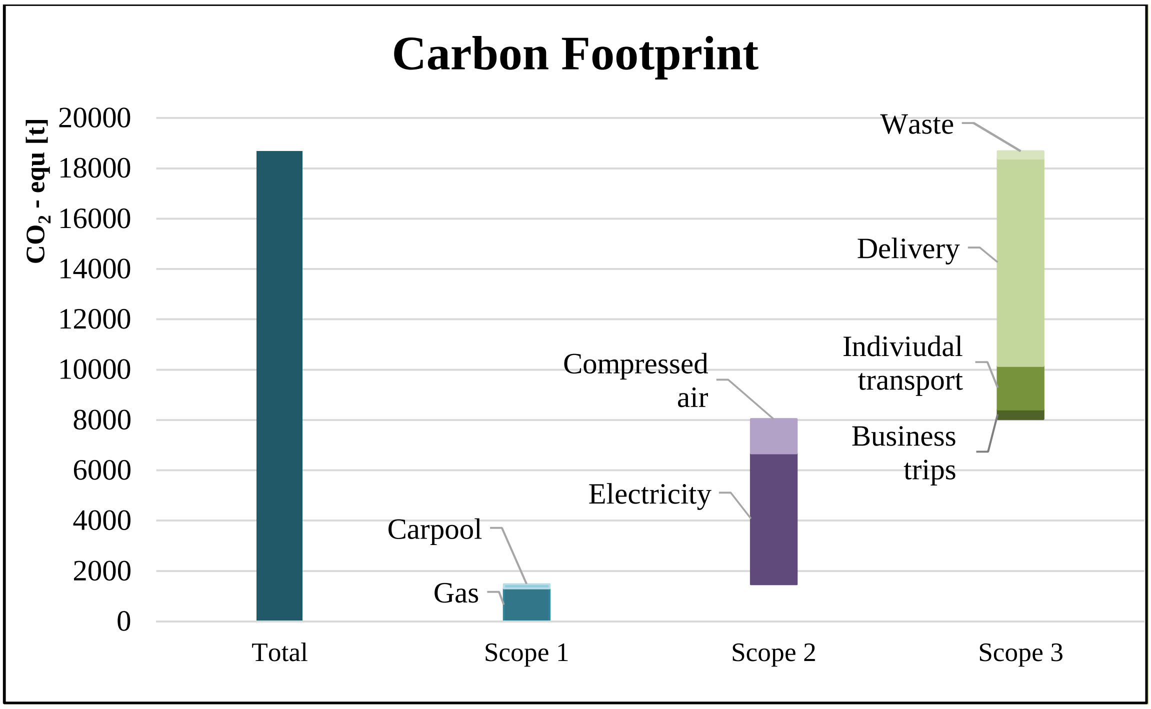

Figure 22: Overall Carbon Footprint (own illustration according to company internal data)

Figure 23 presents a different perspective by visualising the absolute values of the company divided into divisions instead of scopes. To ensure a connection to the other figures, the colours help to differentiate the scopes: the blue tones stand for scope 1, the violet tones symbolise scope 2, and the green ones represent scope 3.

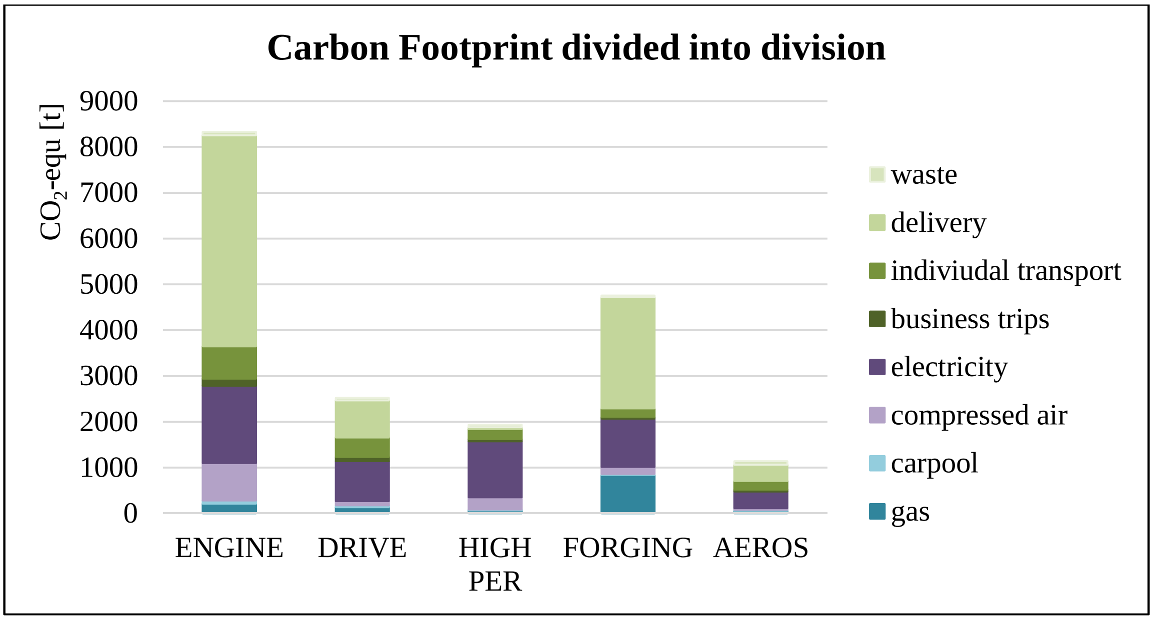

Figure 23: Carbon footprint division (own illustration according to company internal data)

The interpretation of Figure 23 allows for the strengths and weaknesses of every division to be identified. Striking differences can be observed by the topic of deliveries in contrast to electricity, which is approximately evenly distributed. Furthermore, it is remarkable that scope 1 only takes up a small percentage compared with scope 3. Based on these results, individual strategies can be defined and the prioritising of improvement measures can be executed.

Nonetheless, a comparison of the division by using absolute values is not meaningful, because of the different sizes of the divisions. Therefore relative values are created by setting the absolute amount of emissions in reference to company-specific data. Gas, which is used for heating, is associated with the built-up area of the company. Compressed air, electricity, deliveries, and waste are related to the number of working hours. Individual transport is combined with the number of employees; the same applies for business trips and company cars. The corresponding values for this approach are part of Table 5.

At first glance, when considering the absolute values from Figure 24, the division ‘Engine’ covers 44.6% of the overall produced emissions, whereas the division ‘Forging’ is responsible for 25.6% of them. These divisions seem to be the worst polluters of CO_2-equ emissions at Pankl. After transformation into relative values, the divisions appear in a different light. Concentrating the relative values, the ‘Engine’ division is not less favourable than the others and results in a relative value of 16.4%, whereas the ‘Forging’ division raises its impact on the overall view and every individual scope. Considering the relative value ‘Forging’ is responsible for 45% of the emissions. Bear in mind that the divisions require different energy and material inputs in case of their production steps; therefore, the result that a material-changing process has a larger impact than a mechanical-processing step is not unexpected.

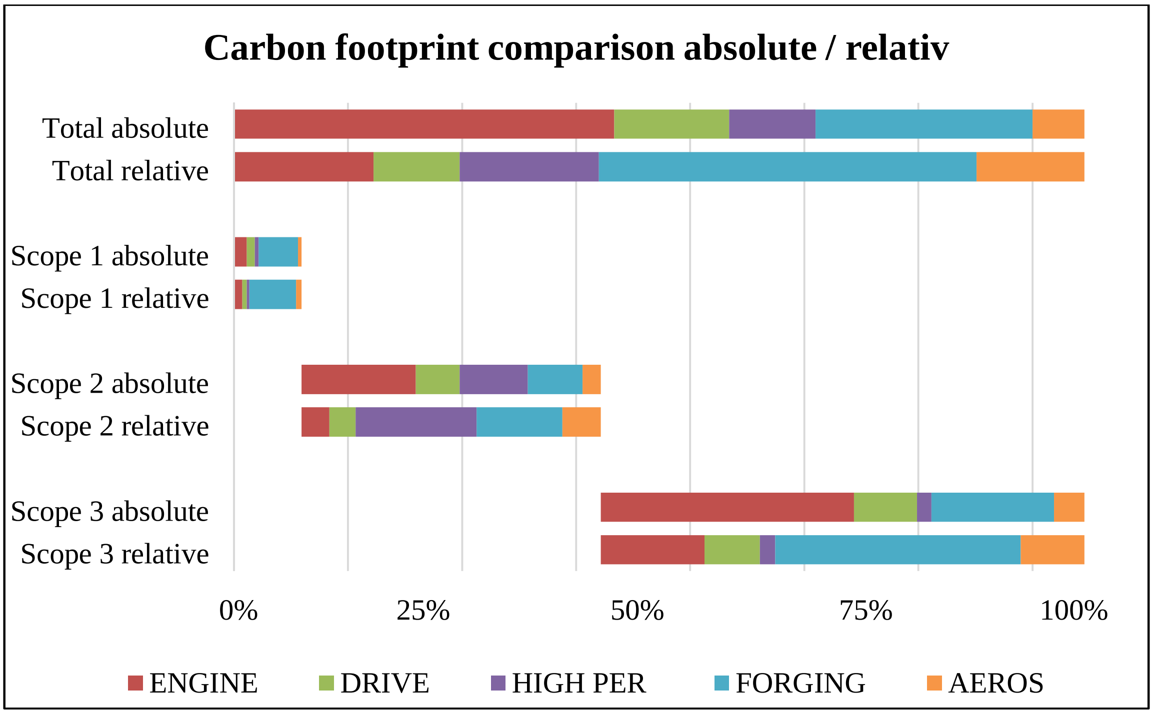

Figure 24: Carbon footprint absolute / relative (own illustration according to company internal data)

7. Strategies for Minimising a Carbon Footprint

This chapter discusses the results presented in chapter 6 and creates potential strategies based on the CCF calculation. It starts with a short introduction on how a carbon footprint can be used as a strategic management tool, and then delineates strategies for how environmental impact can be directly and positively influenced by the company Pankl.

It has to be kept in mind that every new investment in products to reduce emissions might create new emissions. These emissions occur as a result of the manufacturing process, which requires e.g. raw materials and energy sources. Furthermore, they occur through the waste disposal of the eliminated product.

7.1. Operational GHG Management

Operational GHG management is a continuous development and improvement process. It is based on impact assessments and executed in the case of Pankl using CCF calculations. In this process, methods and strategies for climate protection must be planned, coordinated, and documented for all parts of the value chain, starting with functional areas, top management, products, and processes toward the supply chain. The best method of ensuring successful implementation that is comparable to many other areas is the PDCA cycle. The steps in the PDCA cycle are described according to Brinekl (2017, p. 108 ff.) as follows:

i. Plan

The first step is to generate a status-quo analysis, where the identification and quantification of GHGs is executed. Also crucial in this process is to generate an understanding of why and in which form climate change is relevant for the company and where the climate-relevant processes can be found. Based on the results, which include a critical reflection of the company, goals and strategies to reach the targets must be defined.

ii. Do

This step involves the execution of the selected measures. In case of predominant high investment costs in the area for improving environmental performance, the use of pilot projects is common. This approach has the advantage that potential failures can be minimised and false investments reduced. Successful projects can be extended throughout the whole company without high risks, but an intensive exchange of experiences between the involved persons and divisions is necessary.

iii. Check

The third step deals with the review and possible correction of the implemented actions. Measurement and monitoring data are collected not only collected but also analysed. For example, a comparison of the energy usage before and after a set action provides information about the effectiveness. This evaluation is inter alia a decision-maker if a pilot project is executed.

iv. Act

For a continuous improvement process, a proof of the concept must be performed in defined time spans. If the concept has weaknesses, plans and measures have to be adjusted, then documentation of the set actions is part of this stage. If huge changes in the GHG balance are expected, a renewed check must be considered.

Operational GHG management is aimed at economic success through climate protection methods. This success can be divided into internal success potentials, which are relayed within the company, and external success potentials, which are directly affected through the company. A clear separation into the correct category is sometimes not possible. (Brinekl, 2017, p. 227 ff.)

Internal success potentials	External success potentials
• Minimising costs • Reduction of material and energy flows • Reduction of environmental impact • Increase of innovation • Increase of employee motivation • Ethical and moral behaviour	• Superior competitive position • Enhanced image • Decrease of business risks • Satisfying external stakeholders • Differential potential

Table 16: Success Potential (according to Brinekl, 2017, p. 227 f.)

Applying this policy to the company Pankl, the first step in the right direction is taken through this thesis. The analysis of the status quo is executed in Chapter 6 and possible strategies are mentioned in the present chapter. The next step is to prove the practicability of the strategies and request offers so that necessary investments can be planned. The expressed success potentials in Table 16 can motivate companies to make larger investments if not only the climate protection is the sense of achievement.

7.2. Individual Transport

As mentioned in subsection 6.3.3, the data on individual transport are collected using an employee survey. The first part of the questionnaire deals with the general means of individual transport and the distance covered in a single day of travelling (for further details see page 51). The results are that every employee on average travels more than 29 km in each direction, which leads to an overall result of 52,113 km every day for Pankl as a whole. This is approximately 1.33 times around the Earth every day using personal cars from home to work and back. Compared with other emission factors at Pankl, individual transport accounts for 9% of the overall result not the biggest sector, but with huge potential for improvement.

7.2.1. Public Transport

In the second part of the survey, employees are asked why they do not use public transport. To do so, a quantitative method is selected in the form of multiple choice questions. As Figure 25 shows, the main reasons for not using public transport are missing connections followed by losing flexibility.

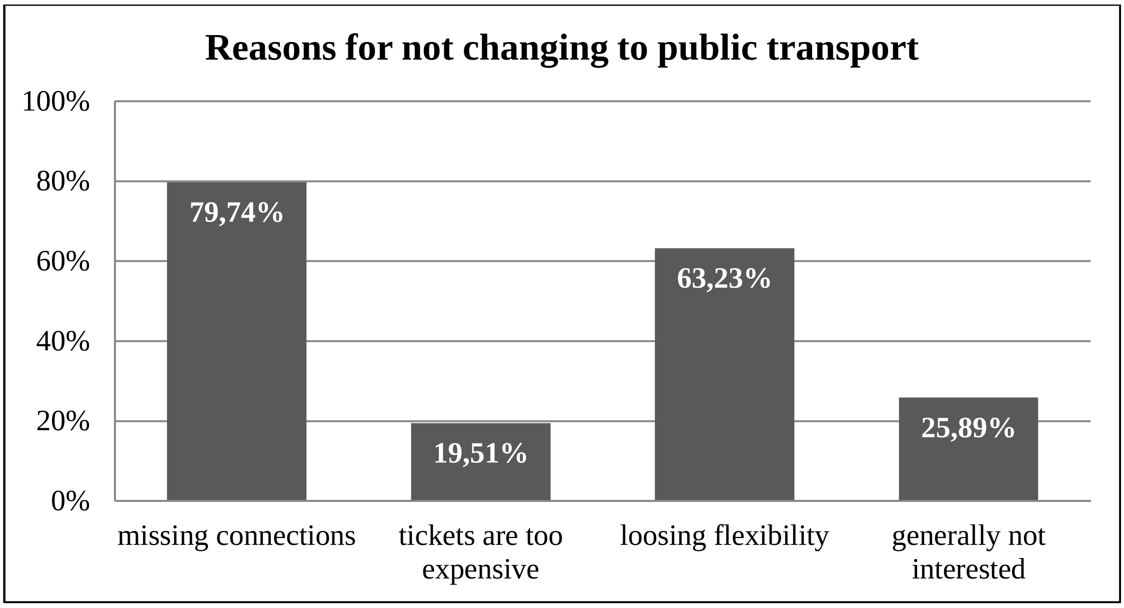

Figure 25: Reasons for not using public transport (own illustration according to company internal data)

The train arrivals at Kapfenberg shows that at least every hour a train from Graz and Mürzzuschlag (ÖBB-Personenverkehrs AG, 2019a, accessed on: 15.04.2019) arrives; however, the closest train station to the plant involves a 20-minute walk (Google Maps, 2019a, accessed on: 15.04.2019). By contrast, the nearest bus station with acceptable arrival frequency (ÖBB-Personenverkehrs AG, 2019b, accessed on: 15.04.2019) is only a 11 minute walk from the plant (Google Maps, 2019b, accessed on: 15.04.2019).

At Bruck an der Mur, a bus stops directly in front of the company; however, the first bus arrives as early as half-past 8 (ÖBB-Personenverkehrs AG, 2019c, accessed on: 15.04.2019) and Pankl's core work time starts at 8 o'clock sharp. If an employee switches to the next bus station with more frequent arrivals, he or she must accept an additional walking distance of 18 minutes (Google Maps, 2019c, accessed on: 15.04.2019).

Considering the abovementioned aspects, the following solutions are suggested:

i. Talk with the respective mayors in charge of the cities to increase the bus arrival frequency or change the arrival time to shift-change times; these are 6 a.m., 2 p.m., and 10 p.m. for Pankl workers. Bearing in mind that many employees have flexible working time agreements, proposing arrival times around 8 a.m. and 5 p.m. could be a compromise, particularly for the location at Bruck/Mur. Examining the bus route of Kapfenberg, the bus clearly changes direction before reaching the Pankl plant; therefore, establishing an additional stop could be a possibility for creating an acceptable situation for the employees.

ii. Another alternative is to implement a bike-sharing system where company-owned bikes or E-bikes are available at the train and bus stations, which can be used to reach the company faster, and vice versa. Modern bikes can be unlocked via QR codes that are scanned by an app, and thus do not need to be tied to fixed stations. This is possible through integrating GPS trackers into bikes, which offers an additional two advantages: this first is that the nearest free bike can be located using an app, and the second is free usage within the allowed area.

In sum, missing connections or stations that are too far away are currently a problem for the employees, and represent a barrier to transitioning to more eco-friendly individual transport to work. This problem can be alleviated through increased arrivals and the implementation of a bike-sharing system. Additionally, the employees will need to be motivated in another way to lose some of their current flexibility, which can be through financial incentives or any other reward.

7.2.2. Electric Vehicles

Additionally to the driving behaviour of the employees, the third part of the employee survey is dealing with the topic of electric vehicles. Therefore is also a quantitative method for questioning selected and is executed in the form of multiple choice questions The aim of this additional questions is to identify if the employees are interested to change to electric vehicles in the foreseeable future. This is asked with the motivation to prove whether the construction of charging stations in front of the company is necessary to fulfil the needs of the employees.

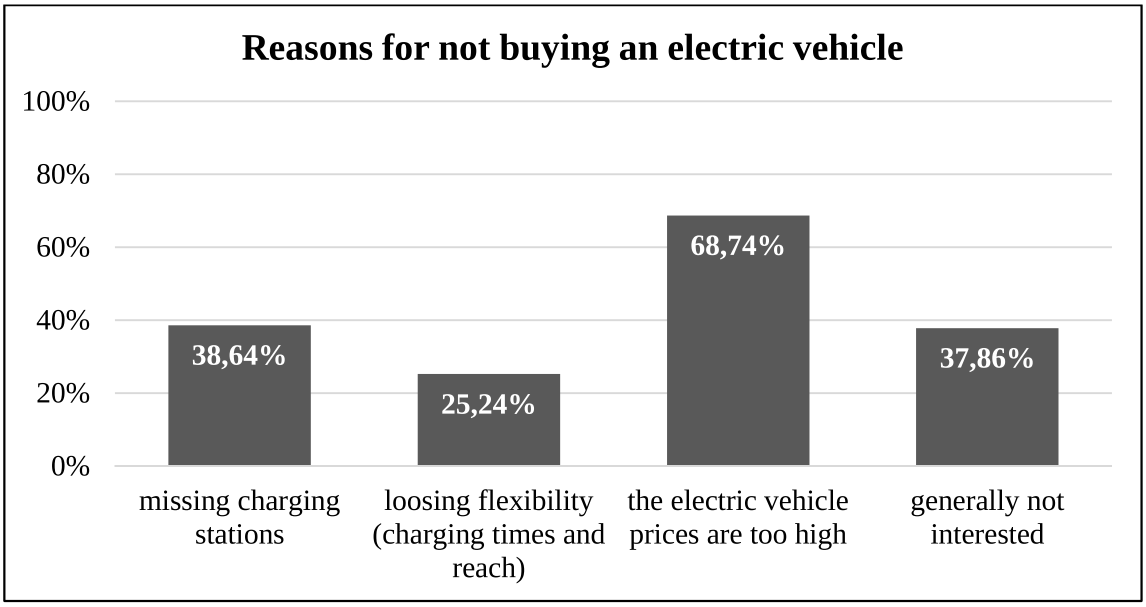

Figure 26: Reasons for not buying an electric vehicle (own illustration according to company internal data)

The results in Figure 26 show that more than two-thirds of employees will not buy an electric vehicle in the foreseeable future because they are currently too expensive. According to the results for means of transport, only two electric vehicles and one hybrid car are presently held by employees. Based on the results, at this point the installation of charging stations is not necessary at Pankl locations because the level of employee interest does not justify the investment.

Changing the point of consideration, Pankl could set a good example by investing in electric vehicles as future company cars. This would have the marketing advantage of an image improvement to stakeholders, as well as a reduction of direct emissions. Additionally, employees would have the chance to experience this form of transport and may lose their scepticism. However, contradictory to what I said before, this would essentially require the construction of charging stations near the company.

7.2.3. Carpooling

Pankl is already encouraging the merger of employees to a carpool with a financial subsidy, but as the results show, the offering is hardly used. Carpooling is a simple but efficient method to reduce emissions; referring to the analysed data, 14.63% of Pankl employees who are using a carpool presently are saving more than 122 tonnes of CO_2-equ every year.

Therefore, Pankl has to teach employees about the benefits of carpooling. The employees will save money by sharing gas consumption and earn additional money from Pankl for sharing cars; moreover, the loss they will experience in personal flexibility is much smaller compared with switching to public transport. The transfer of information can be done in the form of an email to all employees, reminders on the notice board, or in the course of the annual performance review. The goal is to inform employees of this possibility, and in the best case, to motivate them to start carpooling.

7.3. Deliveries

Austria's GHG balance sheet shows that traffic is accountable for 29% of total GHG emissions, which corresponds to 23.7 million tonnes of CO_2-equ emissions. Although Austria is trying to minimise the total emissions by approximately 36% until 2030 compared with 2005, an annual increase in traffic of 2.9% per year is predicted. (Umweltbundesamt, 2019, accessed on: 23.04.2019)

Pankl is also reporting a significant increase in emissions created by deliveries; exactly 44% of the produced CO_2-equ can be assigned to deliveries. However, the least complicated transport from A to B presents numerous variables that are difficult to determine. The main influencing factors for such a consideration are according to Bretzke (2014, p. 129):

- classification of vehicle type (e.g., size, age, fuel type, number of axes, and wheel type)
- shipment weight
- the occupancy rate of the vehicle
- route length
- average driving speed
- external factors (e.g., road conditions, weather, temperature, and traffic)

Regarding these points, only a small percentage of influences is accountable directly to the company. Other than the method of distribution, the weight and route length are under full responsibility of the company, whereas the occupancy rate can only be partially assigned. Considering the core values of Pankl, which are High Tech, High Speed, and High Quality (Pankl Racing Systems AG, 2019), fast distribution is a factor of their success. Based on this, there are two main strategies for the company:

i. Bundle deliveries wherever possible, so that the first and last mile of transport are not done more often than necessary; furthermore, this ensures a higher occupancy rate of the vehicle. To enable a bundled delivery, production planning must consider this aspect, but with the addition that many other factors influence the production plan and the priority of deliveries in this case must be defined.

ii. Identify a more environmentally friendly method of moving goods from A to B. One way to determine the optimal method is EcoTransIT World, which is developed by the Institute for Energy and Environmental Research from Heidelberg, the Öko-Institut from Berlin, and Rail Management Consultants GmbH. It is used by companies of different sizes to plan worldwide routes with multiple transport services. The tool compares the environmental impact of the selected modes of transportation, and finally the user can select the individual best routes and transportation variant. The tool considers possible trans-shipments at frontier crossings and the type of loading locations, as well as particular criteria for each country. It has an easy-to-use interface that shows where the starting point, weight, and end point must be entered, and diagrams present the generated results. Using the tool is generally free of charge, although business licences are also available. The advantage of the business version is that numerous shipments can be calculated at once without manual handling efforts. (IVE mbH, 2018, accessed on: 23.04.2019)

In sum, influencing deliveries in an environmentally friendly manner is a complicated process with many unknown contributing factors. The majority of the impact relies on logistic partners and whether they are already using an effective and sustainable distribution system. Pankl can only affect the number of deliveries to reduce the first mile and select the right logistic partner with the most environmentally friendly vehicles.

7.4. Energy

Purchased electricity is the second largest generator of CO_2-equ pollution within the company Pankl. As demonstrated in Figure 22, this area has significant potential for improvement. Pankl has already started projects to identify its energy hot spots. In one of these analysing activities, which is named ‘energy monitoring’, the daily energy consumption is recorded and energy-intensive processes can consequently be identified. This system has the advantage of enabling the detection of peaks in the energy usage and allowing the company to space out usage evenly if this is necessary and reasonable. The main goal of this approach is to minimise the energy costs, starting with the highest single sources, because the classification is done by sequencing by the maximum values. A method to minimise the impact of electricity consumption is to convert from expended to renewable energy sources. In the following sections, two relevant possibilities are described; furthermore, different strategies for minimising the energy consumption are mentioned.

7.4.1. Renewable Energy

A method to minimise the impact of electricity consumption without restructures within the company processes, is the change to renewable energy sources. In this section, two possibilities are presented how renewable energy can be implemented in the company.

i. Change the electricity supplier:

The first method to minimise the impact of the generation of purchased electricity is to change the electricity supply to a renewable energy source. In the case of Pankl, this means changing from the current provider, ‘energy generation Österreich’, to the environmental label ‘green energy’. With this adaptation, a reduction of more than 92% of the emissions would be possible. However, this reduction of CO2 emissions would come with a massive increase in electricity costs, because green energy is significantly more expensive than traditional energy. Table 17 presents the differences between the energy sources to highlight the impact of the energy generation.

Energy supply	CO_2-equ $[\frac{g}{kWh}]$	Total [t]
Energy generation Austria	0.248	3558
Green energy	0.018	258

Table 17: Energy supply (according to company internal data; Umweltbundesamt, 2017, accessed on: 28.01.2019)

ii. Photovoltaic Systems:

Instead of purchasing all the used energy, Pankl could invest in photovoltaic systems and produce its own energy in future. Such systems have advantages and disadvantages, the most important of which are listed in Table 18.

Advantages	Disadvantages
• CO_2 emissions can be reduced, and the energy that is invested in the production of the system is amortised after five years of usage • The solar energy can be seen as an inexhaustible resource • Flexible systems and modular construction are possible • The life expectancy of the system is between 20 – 25 years	• The system loses power generation capacity over its lifetime. A 10% reduction (approximately) is expected within the first 10 years, followed by an additional 10% during the next ten years of usage. • High investment costs, which are amortised after an average lifetime period of 10 – 15 years • Not all roof surfaces are suitable for installation, because construction and orientation have to be approved • No uniform power output can be ensured, because weather and daytime hours influence the power generation

Table 18: Advantages/Disadvantages Photovoltaic Systems (own illustration according to Märtel, 2019, accessed on: 01.05.2019)

Weighing the listed advantages and disadvantages, an alternative energy specialist should explore the possibility of investing in photovoltaic systems given the present boundaries at Pankl. Nevertheless, only a small percentage of the overall consumption of Pankl could possibly be covered by this alternative method because an average photovoltaic system can only produce approximately 128 kWh per square meter of covered roof-surface (Bundesverband Photovoltaic Austria, 2019, accessed on: 01.05.2019). Factors such as system power, building orientation, and plant location could considerably influence this value. Additionally, the original power supply would have to be maintained, because the photovoltaic system cannot work when there is no sun.

7.4.2. Energy Saving Potential

In contrast to the strategic decision of changing to green energy, this section discusses how to minimise power consumption. Different methods and approaches for saving energy consumption are discussed.

Within a manufacturing enterprise, the power consumption of the office is generally low in contrast to the operational processes, but this is no excuse for not taking actions in this field as well. According to Gründig (2013, p. 28) there is huge energy-saving potential throughout the whole company. The presented values in Figure 27 are collected from all sectors of economy and present the saving potentials of individual mechanisms.

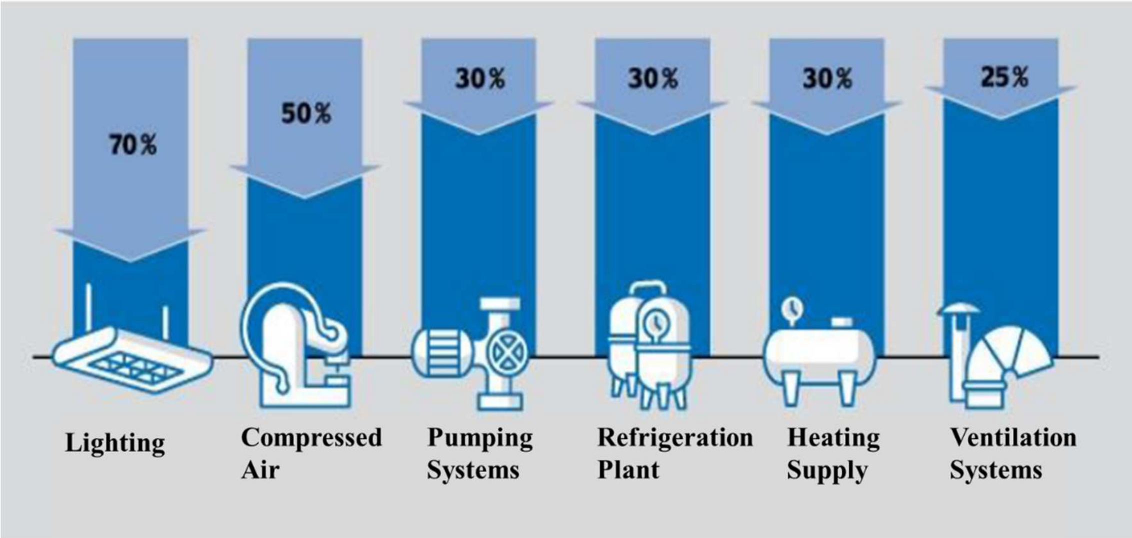

Figure 27: Energy-Saving Potential (according to Gründig, 2013, p. 28 translated)

i. User Motivation

One aspect of energy-saving potential can be handled without any further investments, as it is directly connected to employees' behaviour. Energy can be saved with very simple methods by using the four steps of user motivation, as stated by Grazer Energieagentur GmbH & Umweltamt Graz (2019, accessed on: 24.04.2019):

- **First step: creating awareness**
This step can be addressed by posing short questions about energy saving behaviour in employees' daily lives to demonstrate how energy efficient they currently are.

- **Second step: information**
Giving employees concrete instructions on how they can be more energy efficient by providing short descriptions of suggestions and their importance, can increase employees' effectivity at

saving energy. If an innovative design and animated elements are leveraged, employees will remember the information. Additional email reminders can help keep the topic in mind. Furthermore, reminders in the form of notices (for example, on light switches or desktops) can help. Some examples of simple saving potential in the daily office routine are listed below:

- switching off one’s PC every evening
- the last employee leaving turns all lights off; lights can also be switched off during the day when external light sources are not necessary
- intelligent use of heating and climate
- sufficient air exchange
- thinking before printing

These are only a few thought-provoking opportunities, but they can have a huge impact.

- **Third step: motivation**

The most important factor is to combine environmental actions with fun and personal feelings. Employees can be motivated to be energy efficient through a competition, with an anonymised ranking list or personalised recognition.

- **Fourth step: feedback**

Evaluating energy savings with a visualisation of the results is an important step. Informing the interested parties of what has changed in the period under review enables continued future success.

ii. Lighting Technology

The consumption of energy that is used for electric lighting depends on different factors: on the one hand, room size and room height, and on the other hand, the light fixture type, reflectors, and light output. Simple methods with high savings potential include installing motion detectors in less frequented rooms, using daylight sensors that dim the light, and switching from conventional light bulbs to LED-lamps or eco-halogen lamps. However, the replacement of all functional light bulbs is not only associated with high investment costs; the future disposal cost also has to be taken into consideration. Over the course of any building renovation, it is also useful to paint the walls white and to reduce lamp heights. Another way to increase light output without any investment costs is to clean lights at regular time intervals. (vPRESS. GmbH, 2019, accessed on: 24.04.2019)

iii. Compressed Air

Plants requiring compressed air for operational duty are often not in mind by the thoughts of energy efficiency, but as seen in the recent calculation, the usage of compressed air produces approximately 48 tons of CO_2-equ annually. Pankl has taken appropriate first steps to save energy in this area. Annual leakage monitoring conducted by an external assessor with subsequent maintenance is taking place, but other influencing factors include the age and ultimately the type of the compressor in operation as well as the network of services. Other opportunities for improvement in this area are related to the economic usage of compressed air and the economic usage of end-devices. Possible savings can be ensured through efficient compressor control systems or process optimisation, but the greatest impact is related to the usage of the compressors' wasted heat, which can be used for the generation of warm water or so-called process heat. (vPRESS. GmbH, 2019, accessed on: 24.04.2019)

iv. Pumping Systems, Plant Refrigeration, Heating Supply and Ventilation Systems

The previously mentioned systems have the potential to reduce energy consumption, but they often come with high investment costs. The amount of energy that can be saved depends on the age of the system, the type of network services, and whether the wasted heat can be used or recycled. Subject to the actual conditions of the system, an investment might make sense economically in a few years, but to fully understand the actual circumstances, a specialist needs to be consulted. (vPRESS. GmbH , 2019, accessed on: 24.04.2019)

7.4.3. ISO 50001:2018

As is many other areas, the International Organization for Standardization provides a certificate for systematic energy management, with the aim of implementing a continuous improvement process for energy efficiency. This certification replaced the DIN EN 16001 in June 2011 and is now internationally valid. An advantage of an already –existing environmental management system, such as Pankl has the ISO 14001:2015, is that the implementation of a new system or the advancement to an updated revision of the existing system is easier to handle. It is important to implement individual management systems in an integrated way, instead of in parallel, to save staff, time, and resources. An interaction between energy, safety, quality, and environmental protection enables high potential for success. (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2012, p. 10 ff.).

Energy management includes the sum of all considered systems which have to be planned and executed to function with minimal energy input while generating a maximal output. This includes not only organisational aspects but also technical issues that capture all flows of energy. The aim is to implement an energy policy, define strategic goals, define supporting systems, and to determine how these systems can be captured and quantified. The most important aspects to ensure effective energy management are documentation, monitoring, information, and organisation (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2012, p. 10 ff.).

Arguments for and against an implementation are listed in the Table 19.

Advantages	Disadvantages
• Reduce costs by the way of increasing energy efficiency • Protect environment • Act sustainably from the perspective of resource efficiency • Image, with a certification the plausibility to act energetic efficient is given • Use simplifications in legislation • Look ahead in sense of climate policy	• The certification is expensive • System implementation and maintenance are time intensive • Increased bureaucracy through documentation • The theory is often difficult to practice

Table 19: Advantages/Disadvantages of implementing ISO 50001:2018 (according to Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2012, p. 18)

In sum, the implementation of an additional standard enables a company to establish a basis for constant internal and external pressure for improvement. However, with a motivated team and a set of environmentally friendly company policies, the same goals can be reached without the bureaucratic demands and costs of a certification.

8. Outlook

As mentioned in Chapter 2.3.1, it is possible for companies to trade emissions certificates to reach the defined greenhouse gas reduction goals. This method is called the Europe Emissions Trading System (ETS) in Europe. Energy-intensive industries and energy suppliers have to pay for emission certificates according to their amounts of produced emissions. This system works uses the ‘cap and trade’ principle. The number of certificates is fixed before the trading period starts, and certificates are allocated to the plants according to energy usage. WKO (2017, accessed on: 24.04.2019) mentioned that nowadays the following industry sectors are included in the emissions trading system:

- iron and steel smelting
- coking plants
- refineries and crackers
- cement and limestone production
- glass, ceramics, and brick industries
- paper and cellulose production

The limit values that are relevant for the amount of emission certificates refer to the capacity and performance of the production. If the existing certificates are not sufficient for their volume of emissions, companies must pay penalties for every additional tonne of CO_2. Another possibility is that taxes are levied on emissions; the producer consequently has to bear these costs. Taxes can also impact weak economic groups, but with an efficient use of the earned money a compensation can be created. (WKO, 2017, accessed on: 24.04.2019)

To sum up, a redesign of this emission trading guidelines or the implementation of taxes for emissions could also take other industry sectors into account. Therefore, the reduction of emissions can be seen as a long-term plan for all fields of operation to avoid future problems. The political background is clear: measures have to be set to reach climate goals. The exact design of these measures is not currently defined but will gain importance in the future.

9. Conclusion

This thesis aimed to identify the environmental impact of the company Pankl by using the method of carbon footprint. The calculation model includes company-related and controlled activities in conformity with the GHG Protocol. Therefore relevant GHG are accounted and translated into fitting CO_2-equ. During the year of investigation (01.01.2018-31.12.2018), the overall amount on produced GHGs result in 18.683 tons of CO_2-equ. Against the expectation within a manufacturing enterprise, the used electricity covers only the second largest part with 27.8% of the overall amount of GHG gases. As the most significant contributor is the delivery identified, which covers 44.1% of the impact.

In addition, the present findings are used to enable a comparison of the environmental performance of the five individual divisions within the company. An inspection of the calculated values identifies the division ‘Engine’ as critical because it covers 44.6% of the total amount of emissions, followed by the division ‘Forging’ with 25.6%. Setting the activities defined in the GHG Protocol in connection with reference values, e.g. number employees, number of working hours and manufacturing space, the results are changing. Based on the division size the division ‘Engine’ is losing importance to 16,4% of the total amount of emissions, whereas the division ‘Forging’ is increasing to a critical level of 45%.

These results provide a basis for potential strategies to influence the environmental impact in a positive way. Conceivable solutions for saving energy are renewals on the shop floor, investing in renewable energy sources and motivate employees to act sustainably. Furthermore, an improvement in the sector of deliveries is feasible, by bundle the deliveries and changing the mode of transportation whenever possible.

In summary, the calculated result of the carbon footprint depended mainly on the defined system boundaries and defined assumptions. Core issues for correct calculations not only include generating data and fulfilling the requirements of data accuracy but also the selection of the process- and product-specific CO_2-equ. To ensure comparability between different carbon footprints, the requirements have to be defined in a more precise way, because key factors are currently not sufficiently described. Based on this, the validity of the external examination of the carbon footprint of Pankl is not yet sufficient. However, the current carbon footprint is still a useful tool for measuring environmental performance within a company. Intensive examination of emission sources and an operational GHG management can result in an economic success through the methods of climate protection. Furthermore, the key polluters are already identified, and therefore an individual catalogue of measures can be elaborated upon and executed.

In the future, the identification and measurement of emissions will gain even higher political and financial importance. The emission trading system for all sections or other alternative methods to keep producers accountable will come sooner or later. Therefore, an early analysis of the situation, with the possibility of developing long-term strategic actions to reduce emissions, may help companies avoid undesirable penalty payments in the future.

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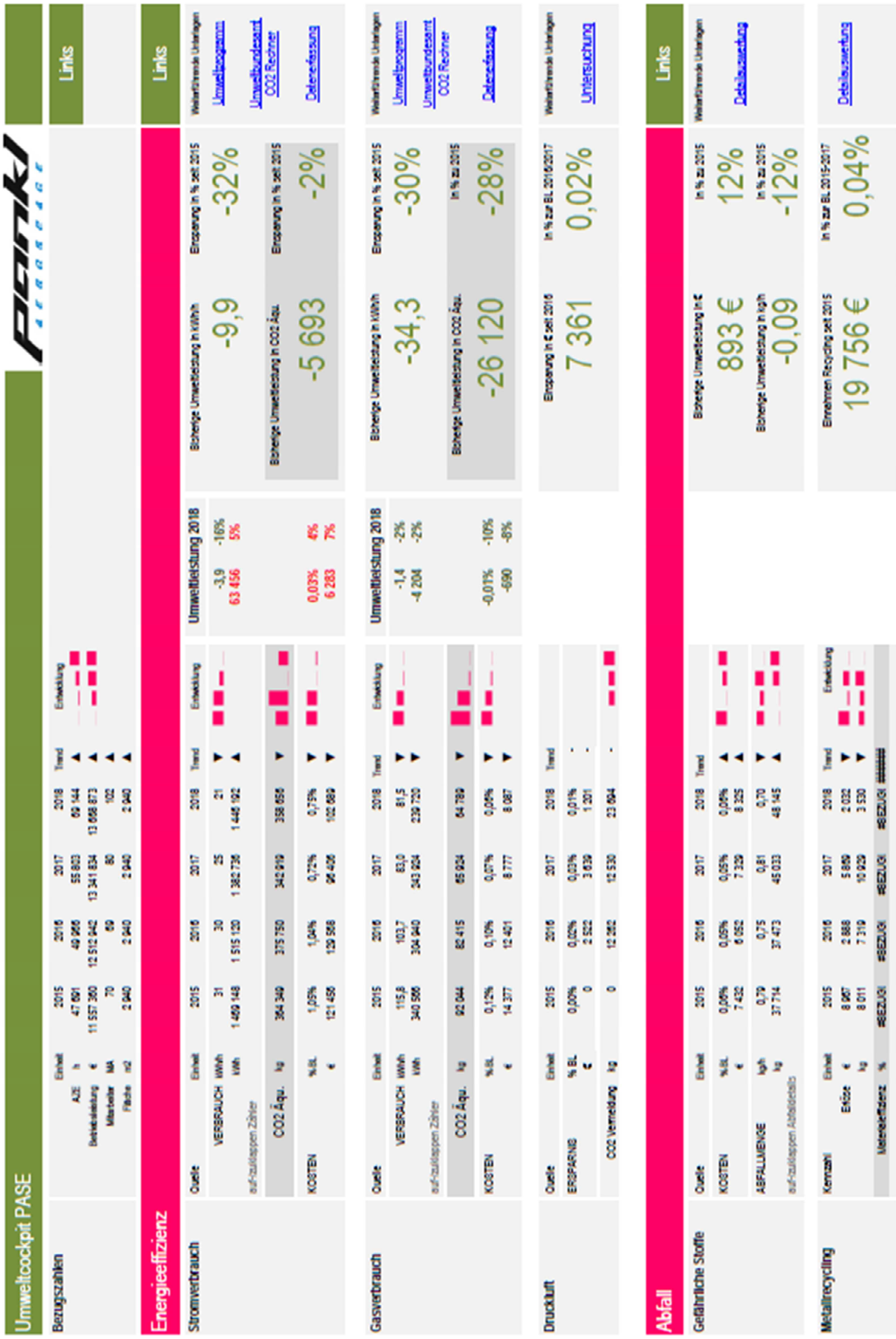
Appendix

Umweltcockpit



Umweltaspekte Matrix

Lebensweg	Prozesse	Umweltaspekte Normalbetrieb: Resourcen – Energieverbrauch: Strom	Gas	Druckluft	Rohstoffverbrauch: Öle / Fette / Schmierstoffe	Chemikalien / Stickstoff	Strahlgut	Treibstoffe	Wasser [1]	UPR	Emissionen – Wasser: Direkt	Wasser: Indirekt	Atmosphäre: Direkt	Atmosphäre: Indirekt	Lokale Auswirkungen: Lärm	Erschütterung	Boden-kontaminierung	Staub	Geruch	Strahlung	Elektromagn-etische Felder	Abwärme	UPE	Abfälle – Abfälle: Unbedenklich	Gefährlich	UPA	Bindende Verfplichtung – Gesetzliche Vorgaben: Gesetzliche Grundlagen	UPBV	U-RPZ
Entwicklung	Produktentwicklung (bei PASE nicht anwendbar)	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-		-	-				
Herstellung	Standort (inkl. Gelände)	3	3	2	2	-	-	1	2	3	-	2	-	3	1	1	-	-	-	-	-	2	3	1	1	1	siehe Bescheide Sharepoint	4	36
	Mechanische Bearbeitung (Drehen, Fräsen, Schleifen, Verzahnen, Sägen)	4	-	3	3	1	-	-	3	4	-	-	2	2	2	-	-	-	1	-	-	3	3	2	3	3	PSA-V 2014, KSS-Erlass des ZAI, IG-L	3	108
	Mechanische Bearbeitung (Magnesium)	4	-	3	3	1	-	-	3	4	-	-	1	1	2	-	-	1	1	-	-	3	3	-	4	4	PSA-V 2014, KSS-Erlass des ZAI, IG-L	3	144
	Schlosserei (Entgraten, Verrunden, manuelles Schleifen, Scotchen)	1	-	1	-	1	-	-	-	1	-	-	2	2	2	-	-	1	1	-	-	-	2	1	1	1	PSA-V 2014	2	4
	Beschriften (Vibro, Gravieren, Ätzen, Ink, Stempeln, Aircraft-Marker)	1	-	1	-	1	-	-	-	1	-	-	-	-	2	-	-	-	1	-	-	-	2	-	1	1	PSA-V 2014, ANVO 2012	2	4
	Montage (Fügen wie zB Vernieten, Einpressen, Montieren)	-	-	1	1	1	-	-	-	1	-	-	1	-	1	-	-	-	1	-	-	-	1	1	1	1	FGV, PSA-V 2014, ANVO 2012	2	2
	Kleben inkl. Vorbereitung	-	-	1	-	3	-	-	-	3	-	-	2	-	-	-	-	-	2	-	-	-	2	1	3	3	PSA-V 2014, IG-L, VbF, ANVO 2012	2	36
	Beschichten (Lackieren) inkl. Mischen und Masking	2	0	2	-	3	-	-	-	3	-	-	3	3	-	-	-	2	3	-	-	-	3	1	3	3	FGV, PSA-V 2014, IG-L, VbF, ANVO 2012	4	108
	Ultraschall-Reinigen	2	-	1	2	2	-	-	2	2	1	-	1	-	-	-	-	-	2	-	-	1	2	-	2	2	PSA-V 2014	1	8
	Reinigung (manuell)	-	-	2	-	2	-	-	1	2	1	-	1	-	-	-	-	1	2	-	-	-	2	1	2	2	PSA-V 2014	1	8
	Rissprüfen (Local FPI, MT, ET)	-	-	-	-	2	-	-	-	2	-	-	2	-	-	-	-	-	2	1	-	-	2	-	2	2	PSA-V 2014, VOPST, IG-L	2	16
	Trockensandstrahlen	2	-	2	-	-	2	-	-	2	-	-	1	1	1	-	-	2	-	-	-	-	2	1	-	1	ExSV, PSA-V 2014, VEXAT	1	4

Employee Survey

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Arbeitsmedizinisches Zentrum

Zusatz-Thema: Individualverkehr

Z1	Bitte geben Sie die Länge Ihres Arbeitsweges in Kilometer an:
54	___________ km

Z2	Wie kommen Sie überwiegend zur Arbeit? (nur eine Antwort möglich)
55	❍1 Auto FILTER (wenn Auto gewählt, dann weiter mit Frage 56, ansonsten weiter mit KFZA) ❍2 Moped ❍3 öffentliches Verkehrsmittel ❍4 Fahrrad / zu Fuß

Z3	Mit welchem Kraftstoff wird Ihr Fahrzeug betrieben? (nur eine Antwort möglich)
56	❍1 Benzin ❍2 Diesel ❍3 andere
	Welches Baujahr hat Ihr Fahrzeug? (nur eine Antwort möglich)
57	❍1 Baujahr 2009 oder älter ❍2 Baujahr 2010 oder jünger ❍3 ich weiß es nicht
	Nützen Sie eine Fahrgemeinschaft? (nur eine Antwort möglich)
58	❍1 ja ❍2 nein
	Wenn Sie an Ihren täglichen Weg zur Arbeit denken, welche Gründe halten Sie davon ab, auf ein öffentliches Verkehrsmittel umzusteigen? (mehrere Antworten möglich)
59	❍1 fehlende Busverbindungen oder zu hoher Zeitverlust durch Wartezeiten ❍2 die Ticketpreise der öffentlichen Verkehrsmittel sind mir zu hoch ❍3 Verlust der Flexibilität ❍4 ich bin generell nicht an einem Umstieg interessiert
	Wenn Sie an Ihren täglichen Weg zur Arbeit denken, welche Gründe halten Sie davon ab ein Elektroauto umzusteigen? (mehrere Antworten möglich)
60	❍1 fehlende Ladestationen vor Ort hindern mich an einem Umstieg zu einem Elektroauto ❍2 Verlust der Flexibilität durch geringere Reichweite und längere Ladezeiten ❍3 die Anschaffungskosten sind mir zu hoch ❍4 ich bin generell nicht an einem Umstieg interessiert

Allgemeine Hinweise:

1) Die Berechnung des CO2-Ausstoßes erfolgt gemäß dem durchschnittlichen CO2-Austoss der Industrie pro kWh Energieverbrauch von 2017 (die 2018-Werte sind noch nicht verfügbar, dürften aber sehr ähnlich sein)

2) Gemäß 1) beträgt der Wert für 2017: ca. 21 Mio. To CO2 und 330 Petajoule Energie (91666 Mio. kWh) -> **0,23 kg/kWh** (Quelle: "Umweltbundesamt - Anteile THG-Emmissionen im Jahr 2017" und "Ministerium Tourismus & Nachhaltigkeit & Tourismus - Energie in

3) Wenn Abfälle verwertet werden (thermisch oder stofflich), so wird jeweils der eingesparte Energieeinsatz gegenüber einer Rohstoffgewinnung aus der Natur berechnet.

Standort Pankl Engine Bruck a.d. Mur

Artikel	Bezeichnung	Schlüssel-Nr.	Menge (to)	Energieeinsatz bzw. -gewinnung in kWh/to	Energieeinsatz bzw. -gewinnung in kWh	CO2-Generierung (To)	CO2-Einsparung (To)	Anmerkung
10020	Gewerbemüll	91101	1,6				1,44	Ersatzbrennstofferzeugung gegenüber gleichwertiger Verbrennung
70030	Aktenvernichtung	18718	5,6				3,36	Stoffliche Verwertung
130010	Altpapier	18718	19,8				17,82	Stoffliche Verwertung
200030	Laugen- und Laugengemische n	52404	1,2	12	14,4	0,003312		
200040	Laugen- und Laugengemische	52402	14,8	12	177,6	0,040848		
200070	Säuren und Säuregemische	52102	25,5	22	561	0,12903		
210080	Emulsion (Bohr- und Schleiföl)	54402	242,4	12	2908,8	0,669024		
220640	Schleifmittel	31444	2,5	13	32,5	0,007475		
240150	Werkstättenabfall	54930	21,1				18,99	Ersatzbrennstofferzeugung gegenüber gleichwertiger Verbrennung
240210	Filtertücher, -säcke	58202	2,8	13	36,4	0,008372		
150150	Kunststoffverpackungen	91207	7,9				39,50	Stoffliche Verwertung
Summe						**0,858061**	**81,11**	
CO2-Bilanzsumme (Einsparung - Generierung)					**CO2-Einsparung in To in 2018**		**80,25**	

Standort Pankl Forging Kapfenberg								
Artikel	**Bezeichnung**	**Schlüssel-**	**Menge (to**	**Energieeinsatz bzw. -gewinnung in kWh/to**	**Energieeinsatz bzw. -gewinnung in kWh**	**CO2-Generierung (To)**	**CO2-Einsparung (To)**	**Anmerkung**
10020	Gewerbemüll	91101	1				0,90	Ersatzbrennstofferzeugung gegenüber gleichwertiger Verbrennung
20060	Bauschutt	31409	1,2	5	6	0,00138		
20310	Strahmittelrückstände nicht sch	31451	6,9	13	89,7	0,020631		
200040	Laugen- und Laugengemische	52402	20,5	12	246	0,05658		
200070	Säuren und Säuregemische	52102	13	22	286	0,06578		
200100	Wässrige Konzentrate	52725	6,3	50	315	0,07245		
210020	Schlamm aus Behälterreinigung	54715	2,7	13	35,1	0,008073		
210130	Öl-Wassergemische	54408	33,6	12	403,2	0,092736		
220470	Metallhydroxitschlämme	51113	18,1	13	235,3	0,054119		
220700	Strahmittelrückstände schädlic	31440	2,6	15	39	0,00897		
240150	Werkstättenabfall	54930	3,5				3,15	Ersatzbrennstofferzeugung gegenüber gleichwertiger Verbrennung
260010	Ölabscheiderinhalte	58202	4	13	52	0,01196		
130010	Altpapier	18718	18,2				16,38	Stoffliche Verwertung
150150	Kunststoffverpackungen	91207	2,9				14,50	Stoffliche Verwertung
Summe						**0,392679**	**34,93**	
CO2-Bilanzsumme (Einsparung - Generierung)					**CO2-Einsparung in To in 2018**		**34,54**	

Standort Pankl High Performance Kapfenberg								
Artikel	Bezeichnung	Schlüssel-	Menge (tc	Energieeinsatz bzw. -gewinnung in kWh/to	Energieeinsatz bzw. -gewinnung in kWh	CO2-Generierung (To)	CO2-Einsparung (To)	Anmerkung
170050	Altholz unbehandelt	17201	0,7				0,49	Stoffliche Verwertung
200040	Laugen- und Laugengemische	52402	3,4	12	40,8	0,009384		
200070	Säuren und Säuregemische	52102	13	22	286	0,06578		
200100	Wässrige Konzentrate	52725	5,6	50	280	0,0644		
210080	Emulsion (Bohr- und Schleiföl)	54402	45,6	12	547,2	0,125856		
210130	Öl-Wassergemische	54408	2,3	12	27,6	0,006348		
240150	Werkstättenabfall	54930	11,7				10,53	Ersatzbrennstofferzeugung gegenüber gleichwertiger Verbrennung
240170	Eisenmetallemballagen	35106	1,3	15	19,5	0,004485		
250180	Laborabfälle und Chemikalienr	59305	2	20	40	0,0092		
120020	Karton	91201	13,5				12,15	Stoffliche Verwertung
130010	Altpapier	18718	9,3				8,37	Stoffliche Verwertung
150150	Kunststoffverpackungen	91207	4,5				22,50	Stoffliche Verwertung
Summe						**0,285453**	**54,04**	
CO2-Bilanzsumme (Einsparung - Generierung)					**CO2-Einsparung in To in 2018**		**53,75**	

Standort Pankl Drivetrain Kapfenberg								
Artikel	**Bezeichnung**	**Schlüssel-Nr.**	**Menge (to)**	**Energieeinsatz bzw. -gewinnung in kWh/to**	**Energieeinsatz bzw. -gewinnung in kWh**	**CO2-Generierung (To)**	**CO2-Einsparung (To)**	**Anmerkung**
170050	Altholz unbehandelt	17201	21,1				14,77	Stoffliche Verwertung
180020	Altöle gem. AWG	54102	2,2				2,20	Stoffliche Verwertung
200030	Laugen- und Laugengemische m	52404	1,8	12	21,6	0,004968		
200040	Laugen- und Laugengemische	52402	2,4	12	28,8	0,006624		
200130	Spül- und Waschwässer	52714	2,4	50	120	0,0276		
210080	Emulsion (Bohr- und Schleiföl)	54402	136	12	1632	0,37536		
240130	Spraydosen	59803	1,7	12	20,4	0,004692		
240150	Werkstättenabfall	54930	7,1				6,39	Ersatzbrennstofferzeugung gegenüber gleichwertiger Verbrennung
130010	Altpapier	18718	25,1				22,59	Stoffliche Verwertung
150150	Kunststoffverpackungen	91207	6,3				31,50	Stoffliche Verwertung
Summe						**0,419244**	**77,45**	
CO2-Bilanzsumme (Einsparung - Generierung)					**CO2-Einsparung in To in 2018**		**77,03**	