Calculating the carbon footprint of universities

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Executive summary

Environmental issues are becoming increasingly important in the agenda of organizations. If organizations want to reduce their CO2 emissions, then it is important to be able to measure this. This research focuses on the calculation of carbon footprints at universities. Related issues, like allocation of carbon footprints, information systems used for calculating the carbon footprint and the uncertainty of calculations are also topics of this research. Wiedmann and Minx (2007) provide the following definition of a carbon footprint: “The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product”. Furthermore, “the ‘total amount’ of CO2 is physically measured in mass units (kg, t, etc)”. This is the definition that I used for my research.

Several standards are available for the calculation of the carbon footprint. However, some issues are under-addressed there, like the role of information systems in calculating the carbon footprint, and allocation of emissions within the organisation. Furthermore, most past research focused on CO2-equivalents instead of CO2 emissions in particular. The goal of my research was to create a model to calculate CO2-specific emissions for the EUR, to discuss whether this model can be generalized, and to discuss related issues like allocation and information systems. Therefore, I defined a broad research question that allowed me to cover lots of aspects of calculating the carbon footprint:

How should Erasmus University Rotterdam and other universities calculate their carbon footprint?

First, a literature review was done to get an extensive understanding of how a carbon footprint can be calculated. Second, the literature was analyzed to see what standards I could use for my research. In addition, reports of universities that had calculated their CO2 emissions were analyzed to see what emission categories were significant for other universities. These analyses led to a basic description of my model; a basic description of how the carbon footprint could be calculated. Third, a case study was done. In the case study, I calculated the carbon footprint of Erasmus University. In this section, an elaborate description of the model that I used to calculate the carbon footprint of the EUR has been given. Fourth, taking the results from the literature review, analysis and case study together, several topics that relate to carbon footprint calculations for universities have been discussed. Finally, the results from the discussion were used to answer my research questions.

In the literature study, the most important standards and scientific papers have been consulted, to get more knowledge on the ways in which a carbon footprint can be calculated and to provide me with information on past research. The Greenhouse Gas Protocol (WRI & WBSCD, 2003) and the Campus Carbon Calculator (CA-CP, 2010) turned out to be the most usable methods for calculating the CO2 emissions of a university.

The total CO2 emissions of an organization like a university can be split up according to three different scopes. Each scope can be subdivided into different categories. Scope 1 contains the emissions that a university has from using company-owned assets. Examples of emission

categories in scope 1 are home-made electricity and transportation of vehicles owned by the organization. Scope 2 contains purchased heat and purchased electricity. Scope 3 is about other emissions that are not the result of company-owned assets, but are the result of a company's activities. Employee commuting (in non-company owned vehicles) and purchased water are examples of these emission categories.

For each emission category, activity data and emission factors are needed for the CO2 calculation. Activity data relate to the activity that produces an emission (i.e. the amount of electricity used in terms of kWh), while emission factors express the amount of CO2 that is consumed for each unit of activity data. For example, an emission factor for electricity is expressed in kg CO2 / kWh. Sometimes, emission categories contain subcategories. For example, the category "employee commuting" is split into the subcategories gasoline, train, tram, etc.

Using the information from the standards and specific information about carbon emissions by Erasmus University Rotterdam (EUR), a model has been created. This model uses input from various emission categories to calculate the CO2 footprint of EUR. The tool that is most closely related to my model is the Campus Carbon Calculator (CA-CP, 2010). The following features distinguish my model from the Campus Carbon Calculator:

- My model focuses on CO2 emissions only, rather than CO2 equivalents (which is a measure that incorporates greenhouse gas emissions (GHG emissions), hence more gases than just CO2).
- Some emission categories that are not relevant for a CO2-only calculation have been removed in my model
- My model calculated the CO2 emission of water usage, paper consumption and waste, which is not the case for the Campus Carbon Calculator (when it comes to CO2 in specific)
- More emission subcategories were used for student commuting, employee commuting and waste

To calculate the total CO2 emission for EUR, a time-consuming task was collecting the activity data. The activity data is spread throughout the EUR, and some desired data even turned out to be unavailable. Sometimes, pre-calculations or estimations were necessary to get the required activity data. Still I managed to calculate the carbon footprint of EUR. A split was made between the emissions of education and research by using a simple allocation key that allocates 60% of the emissions of a certain category to research and 40% to education whenever allocation was necessary. The results are visible in the table below:

Scope	Emission category	Research CO2 emission kg CO2	Education CO2 emission kg CO2	Total CO2 emission kg CO2	Total CO2 emission %
Scope 1					
	On-campus stationary sources	8.189	5.460	13.649	0,11%
	Direct transportation sources	799	532	1.331	0,01%
Scope 2					
	Purchased electricity	552.097	368.064	920.161	7,30%
	Purchased heat	953.145	635.430	1.588.575	12,61%
Scope 3					

	Employee commuting	996.388	664.259	1.660.647	13,18%
	Student commuting		7.763.420	7.763.420	61,61%
	Employee travels	336.988		336.988	2,67%
	Water usage	30.185	20.123	50.309	0,40%
	Paper consumption	44.779	29.853	74.631	0,59%
	Waste	65.295	43.530	108.824	0,86%
	Electricity T&D losses	49.689	33.126	82.815	0,66%
	Total	3.037.553	9.563.797	**12.601.349**	100,00%
	Total per student*		521	521	
	Total per diploma*		1.669	1.669	
	Total per employee	1.217	3.833	5.051	
Totals	Total per FTE	1.611	5.073	6.684	

The total CO2 emission of the EUR is 12,6 million kg CO2 in 2010. Commuting is responsible for the majority of the emissions of Erasmus University, with student commuting being responsible for 61,6% of the total emission, and employee commuting is responsible for 13,2% of the total CO2 emission. Other important sources of emissions are purchased heat (12,6%), purchased electricity (7,3%) and employee travels (2,7%). I compared the emissions of Erasmus University Rotterdam with the University of Toronto (UoT) and Lakeland Community College (LLC). Total emissions per student and per employee were a lot lower for the EUR, when compared to UoT and LLC. Emissions of commuting and employee travelling at the EUR were (per person) quite comparable to the UoT, while LLC had much higher emissions for these categories than EUR and UoT. However, the emissions of heat and electricity at the EUR were a lot lower than for UoT and LLC. This caused the big difference in CO2 emissions between the EUR and the other two organizations. What we can learn from these comparisons is that the EUR saves CO2 emissions, due to their green electricity. Furthermore, the way heat is provided (by using "Stadsverwarming") has also reduced CO2 emissions for the EUR.

There is some uncertainty in the numbers displayed in the table above. Uncertainty in the activity data is an important reason for this. I developed a new method to represent the uncertainty. For EUR, the perceived uncertainty of the activity data of each emission category is stated in the table below. This uncertainty is stated along with a description of how the activity data was obtained; the uncertainty is directly related to the method of obtaining activity data. In the table below, M means that the activity data is the result of a measurement. C1 means a calculation with low uncertainty, C2 a calculation with medium uncertainty and C3 a calculation with high uncertainty:

Scope	Emission category	Method of collecting/calculating the activity data	Uncertainty
	On-campus stationary sources	The amount of natural gas used is measured	M
Scope 1	Direct transportation sources	Dividing the total amount of km travelled by each car by the estimated age of the car (based on the year that the cars were bought). Then summing up the estimated km for both of the cars	C2

	Purchased electricity	The amount of purchased electricity is measured	M
Scope 2	Purchased heat	The amount of purchased heat is measured	M
	Employee commuting	The distance between the university and each employee is calculated by using a tool that estimates travelling distance, based on two ZIP codes (employee ZIP code and university ZIP code) In the survey, employees could fill in their mode of transportation. Based on this, the estimated travelling distances is allocated to a transportation mode. Sometimes multiple modes of transportation were filled in. Based on an estimation, the estimated distance per trip is allocated to different transportation modes The estimated total distance (km) is calculated over an entire year for each transportation mode over the total of 1028 employees that filled in the survey This distance is then used to estimate the total travelled distance of all the employees (2113)	C2
	Student commuting	Same method as for employee commuting. 1548 students filled in the survey. This data is used to estimate the total travelling distance of 18366 students	C2
	Employee travels	Data sheets with all the travels and their destinations are gathered from the faculties. Distances to the destinations are not part of the data sheets. Distances are then estimated by using tools on the internet, or the estimations of the distances that are used for a previous CO2 calculation of EUR For almost all of the data, the transportation mode was not given. Therefore, rules are set up to allocate distances to train and air, based on the travelling destination. Flight distances are allocated to European to Non-European air travel, based on the destinations. The total flight distances and train distance are calculated by adding up all the distances from the individual travels.	C2
	Water usage	The water usage is measured	M
Scope 3	Paper consumption	Two sources of data are used for paper consumption: purchasing data from the EFB (Erasmus Facilitair Bedrijf) and data from the Service Point Copyshop. The EFB data contained the total weight of the purchased paper. The Copyshop only gave me an estimation of the amount of sheets that they used in one year. This amount of sheets is used to estimate the total weight of the Copyshop paper. This estimation is added to the total weight of the	C2

		purchased paper of the EFB to get the estimated total paper consumption for EUR	
	Waste	Activity data was necessary for residual waste, paper and cardboard, confident paper and glass. For residual waste and paper and cardboard, the total weight was known. For confident paper and glass (a small proportion of the total waste), only the volume and amount of containers that are processed by Van Gansewinkel (company that processes waste) are known. The volume, the amount of containers, the estimated proportion of glass and confident paper of the container (part of the container is filled with air) and the density of paper and glass is used to estimate the total weight of the confident paper and glass waste. Swill waste is not included in the calculation, because the available data was not sufficient.	C3
	Electricity T&D losses	T&D losses are calculated based on the electricity usage, which is measured.	M

When taking a weighed average (by using the percentage of the total CO2 emission of each emission category), the average uncertainty of the activity data is C2, medium uncertainty. I came to this conclusion, because the emission categories with a C2-level uncertainty constitute 78,72% of the total CO2 emission of the EUR.

Knowledge from the literature and the case study has been taken together to discuss several issues in the field of carbon footprinting, enabling me to give an answer to my research question:

How should Erasmus University Rotterdam and other universities calculate their carbon footprint?

There are a few emission categories that I consider mandatory to include in the CO2 calculation for each university: electricity, heat, employee commuting, paper and employee travel. Furthermore, I recommend that universities also include emissions of student commuting, waste, water, electricity T&D losses, other on-campus stationary sources, water and direct transportation. After deciding what the emission categories should be, activity data and emission factors have to be gathered for all the emission categories. The total CO2 emission of the university should be calculated by multiplying emission factors and activity data for all the (sub)categories; taking the sum of these multiplications gives the total CO2 emission of the university. The degree of uncertainty of the calculations can be assessed by doing a sensitivity analysis.

I recommend that the CO2 emission for each emission category at EUR would be allocated to research and education in a subsequent calculation, because the required effort for doing this is not high and it gives the possibility to use measures such as CO2 per student and CO2 per publication. I also recommend this for other universities. I do not recommend allocation among different faculties for EUR, because the required data for doing this accurately is not sufficiently available and emissions are more influenced by university policy, rather than faculty policy. Other universities should make their own decision regarding this. The decision should be based on the time required to do the allocation, the present data and quality of the information system in the organization and on whether faculties could influence their own carbon footprint.

Universities should use an advanced information system for calculating their carbon footprint, when I look at the issue from an environmental viewpoint. However, universities should decide whether investing in such an expensive tool would be worth the money and time. Calculating the carbon footprint by using a simple, Excel-based tool like my model or the Campus Carbon Calculator is also possible and it is free, except for the required effort. This is obviously better than not systematically calculating the carbon footprint, which is currently the case for EUR. The model that I created for EUR can be used by other universities. However, some emission categories may be added or removed, and some emission factors may have to be changed.

Universities should also invest in simple programs collecting and processing the data. For example, the mobility survey could directly calculate the distances for each travelling method. Regardless of the calculation method that is used, such programs could automatically provide activity data for the calculation.

Measuring the carbon footprint on a structural basis is not only important from an environmental viewpoint, but may also provide financial and reputational benefits. The expenses of EUR in energy and water amounted to 9.3 million Euros in 2010, which is 28% of EUR's total housing costs (Erasmus University, 2011). The annual expenses on employee travels amounted to approximately 1,5 million euro (including hotel expenses). Measuring the carbon footprint on a structural basis, whether using a relative simple tool like the one developed in this research or a more advanced method, will provide a strong incentive to reduce the carbon emissions and hence to save a substantial amount of costs. Also, an increasing number of universities, internationally but also in the Netherlands, are already measuring their carbon footprint. EUR should move in pace with this development and start measuring and reporting about their carbon emissions, and take their social responsibility in mitigating the effects of climate change and environmental pollution created by their operations.

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1 Introduction

1.1 Introduction to carbon footprints

Nowadays there are a lot of discussions about carbon emissions in the world. Carbon dioxide (CO_2) emissions can cause problems in the future, because it is the main contributor to the greenhouse effect (Time for change, 2007; Holzman, 2008). The greenhouse effect can cause changes in climates in the world. Due to a rising temperature, ice can melt, raising the level of the sea, possibly causing floods in lower areas. In addition, some areas might get dryer and some may get more moisture. Increasing dryness in Africa already causes problems for agriculture and hunger (Milieu Centraal). Climate change also effects biodiversity as a result of changing seasons, effects oceans and coral reefs in particular, endangers the food supply in the world as a result of crop failure and even gives rise to conflicts when land and houses of people, as well as their food supply are endangered.

Companies are a major contributor to climate change. Companies therefore play an important role in mitigating the effects of climate change. An increased amount of companies have started to acknowledge their responsibility towards climate change and have defined targets to reduce their carbon emissions. Defining these targets and measuring the progress of working towards these targets starts with measuring the company's current amount of CO_2 emissions. Because of the carbon dioxide problem, it can be good for some companies to keep track of their CO_2 records. Legal requirements or an environmental-friendly image are examples of reasons for companies to produce environmental reports (Perrini & Tencati, 2006). Furthermore, eco-efficiency correlates positively with financial performance (Guenster et al, 2006). Lowering CO_2 emissions is a way of being eco-efficient. Measuring CO_2 emissions is necessary to reach emission reductions. Therefore, keeping track of the CO_2 emissions leads to financial benefits for companies as well.

Greenhouse gas emissions (GHG emissions) are often calculated in kg CO_2 or in kg CO_2e. Aside from CO_2, other greenhouse gases such as methane (CH_4) are also reflected in the CO_2e measure. When a measurement is done in kg CO_2, then only carbon dioxide emissions are accounted for.

This research is about the calculation of the carbon footprint for universities. There are multiple possible definitions of a carbon footprint. Wiedmann and Minx (2007) give the following definition of a carbon footprint: “The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product”. “The ‘total amount’ of CO_2 is physically measured in mass units (kilogram, metric tons, etc)”. More definitions of the carbon footprint are discussed in the literature review.

1.2 Problem statement

When calculating a carbon footprint, many questions arise. Organizations can have many activities that cause CO_2 emissions. Examples of possible emission sources are transport, electricity, paper, manufactured products, clothing, food, drink, health, hygiene and many more (Wiedmann & Minx, 2007; SEI et al, 2006; GAP et al, 2006).

It can be hard for an organization to decide which emission sources to account for in their carbon footprint. There are so many possible sources of emissions in companies that it seems impossible to exactly calculate the carbon footprint of a company. But if calculating the exact carbon footprint is impossible, what rules should be used to calculate a carbon footprint? What information systems should be available for this? Which emission sources should be included in calculating the carbon footprint? How can emissions of an organization be allocated to certain divisions of the organization? These are all relevant questions to companies that want to report about their carbon footprint.

Several models are available for calculating carbon footprints of organizations. The topic of my research is the carbon footprint of universities. Many calculation methods are available, even for universities specifically. However, some things are missing in these methods. For example, I have not found any framework that allocates emissions of universities between research and education. Allocating emissions between research and education can be useful to be able to report CO2 emissions per student, per diploma or per scientific publication. Furthermore, I believe there is a lack of attention to information systems in the literature that I reviewed. I believe information systems are very important for carbon footprint calculations, since the efficiency and reliability of carbon footprint calculations heavily rely on the way that information systems keep track of the data being used for these calculations.

1.3 Reasons of reducing carbon footprints for organizations

Carbon footprints can be measured by organizations to reach certain goals. If a company wants to reduce their carbon dioxide emission and report on this, then a necessary step would be to quantify their emissions in a certain way. In this paragraph, I examine what incentives organizations could have for publishing and reducing the carbon footprint. Measuring the carbon footprint is necessary for organisations to define targets and to keep track of the progress made to reaching their targets in reducing their emissions. Also, this information can be used by companies and organisations in general to report about their emissions, whether that reporting is mandatory or voluntary. Organisations can have several reasons to keep track of their CO2 emissions; as a way to reduce costs by reductions in energy and material usage, to improve reputation and out of a pure sense of responsibility to prove that reductions of CO2 emissions are reached. The carbon footprint is one of the most important metrics that companies report on in their environmental, sustainability or ethical report and an important metric for determining the environmental performance of a company.

De Vries (2011) stated several financial benefits of a good environmental performance for companies. First, when companies are careful about using resources, then this can lead to a higher eco-efficiency. This means that companies can provide more products and/or services with fewer resources. Second, good environmental performance positively influences the reputation of a company. This could not only attract more customers, but also works positively on other stakeholders like media, governmental institutions, employees, investors and potential partners. Third, a superior environmental performance may lead to a competitive advantage. Competitive advantage can be gained by being a leader in the market of by first movers' advantages (Porter & van der Linde, 1996). Fourth, it can lead to fewer lawsuits and other legal conflicts, because a good environmental performance limits the risk of environmental malpractice. Fifth, cooperation from government is easier to get when environmental performance is good, for example, access to permits can be easier. Sixth, superior environmental performance may increase job attractiveness; it results in less employee turnover, because it makes people more proud of their work.

Guenster et al. (2006) did research on the relationship between eco-efficiency and financial performance. Eco-efficiency can be defined as “creating more value with fewer environmental resources resulting in less environmental impact”. A literature review and an empirical analysis were done by Guenster et al (2006). The literature that was used for this was not consistent on the relationship between eco-efficiency and financial performance. Some critics mentioned that CSR (corporate social responsibility) increased costs and decreased shareholder wealth. Obviously, financial investments may be needed to improve environmental performance of a company. For production and manufacturing companies, changes in production and manufacturing processes can be necessary, which cost time and money.

However, there is a positive relationship between eco-efficiency and financial performance according to most of the literature that was consulted in the literature review. In this literature, a number of reasons are mentioned about why eco-efficiency could lead to a better financial performance. Some reasons are similar to reasons that we already mentioned in the previous paragraph: reputational advantages, more efficient use or resources, avoiding financial penalties from the government and sales benefits for customers that are sensitive to social issues. There were also some additional reasons mentioned in the literature review of Guenster et al (2006). First, eco-efficiency may improve an investor’s trust in the company. Second, goodwill can be generated and new market opportunities can be created by displaying social and environmental awareness (Porter & van der Linde, 1996, Guenster et al, 2006). Third, some publications stated that equity returns and firm value are (on average) higher for eco-efficient companies. Fourth, the stock price may increase as a result of positive environmental information about a company.

In their empirical research, Guenster et al. (2006) compared several firms with each other on eco-efficiency and financial performance. A positive relation was found between eco-efficiency and financial performance in their research. For this research, Guenster et al, as academics from Erasmus University Rotterdam, were awarded the 2005 Moskowitz Prize for Socially Responsible Investing.

All in all, not all literature is consistent on the connection between eco-efficiency and environmental performance. However, most research shows that there is a positive relation between these two variables. This suggests that even organizations that are not concerned with the environment themselves should improve their eco-efficiency for their own financial benefit.

Similar arguments can be given for Erasmus University Rotterdam to reduce and measure their CO2 emission. Reductions in CO2 emissions can be paired with financial benefits. For example, less CO2 is emitted if less electricity is used and if employees would use less paper. Furthermore, a lower CO2 emission can result in a better image of the university for students, employees and other universities. In addition, job attractiveness may increase if the EUR proves that CO2 reductions are taking place. However, to be able to report on this, measurement of the CO2 emission is necessary.

The EUR should measure CO_2 emissions to prove emission reductions. The web page of the EUR states that the carbon footprint of Erasmus University Rotterdam should be reduced by 30%. However, no calculations of CO_2 emissions are done by the EUR at the moment, except for a tiny calculation that only incorporates natural gas, heat and electricity. But there are a lot more sources of CO_2 emissions for EUR, which are perhaps even bigger sources of CO_2 emissions than gas, heat and electricity.

At Erasmus University Rotterdam, alterations are being done to buildings. These alterations will influence the CO_2 emission of the EUR. An example of such changes for the EUR is the heat pump that is going to be installed (Erasmus University Rotterdam, 2008). A heat pump is a device that allows heat that refrigerators or air-conditioning emit to be used to heat the buildings. To be able to report accurately on these kinds of changes, the carbon footprint of the university should be calculated. Measuring CO_2 emissions would fit with the "greening the campus" initiative of EUR. If the EUR wants to green the campus, then proof of this can be provided by accurately measuring CO_2 emissions. Similar reasons can be given for calculating carbon footprints of other universities.

1.4 Research objective

In the previous paragraph, reasons were given for why it could be beneficial to companies to measure the carbon footprint. In my research, the focus is on how to measure the carbon footprint of a university. The objective of my research is to provide a model that universities can use for their "carbon dioxide accounting". The model provides a method that can be used for universities to calculate their carbon footprint, and allocate it to different outputs that they have: research and education. The model is tailored to the situation of the Erasmus University Rotterdam, but it can also be used by other universities. Aside from the calculations, several topics are discussed in this research: environmental data, information systems, uncertainty in the calculations and boundaries of the framework. My research should give a detailed explanation of how a carbon footprint can be calculated for universities. Furthermore, the extent to and the way in which my model can be used by other universities is discussed in my research.

1.5 Research questions

The main research question:

How should Erasmus University Rotterdam and other universities calculate their carbon footprint?

To answer the main research question, several sub questions have been defined. Each sub question can be investigated using a number of investigative questions (Blumberg et al, 2008). The sub questions and each of the corresponding investigative questions are given below:

How much detail should be included in CO_2 administrations?

- Which activities should be included when calculating the CO_2 footprint of an organization?

- What are the boundaries for including activities in the accounting scheme?
- How can footprints be allocated when goods and services are purchased? Should the footprint be transferred?

How should information be gathered, processed and presented?

- Which data and IT is needed to make the calculations?
- To what extent should simplifying rules/calculations be used?
- What rules should be present in the calculations?
- How can the degree of uncertainty of the calculations be assessed?

How can emissions be allocated to the various objects that cause CO2 emissions?

- How can footprints be allocated to different outputs of a university?

How can differences between different organizations be incorporated into the model?

- Should the green accounting rules be the same for all organizations?

1.6 Scope

Environmental accounting is a very broad topic. Because the allocated amount of time for this thesis is limited, a scope has to be defined. Below the scope of my research can be found:

- I focus on calculating the carbon footprint of universities. My focus is not on the carbon footprint of other types of organizations. Furthermore, consolidating environmental data of organisations for environmental accounting on a regional or national level is not part of the scope of this research (although it may briefly be discussed).
- Transforming carbon dioxide emissions data into financial data is not the focus of this research. Monetary environmental accounting is not the focus of this research.
- I focus on carbon dioxide (CO2). Carbon dioxide equivalents (CO2e) or other types of emissions or waste are not part of the focus of this research.
- The focus in this research is on calculating data and performing certain calculations on the data. How to use the data in an optimal way for decision making purposes is not part of the focus of this research.
- Compensating CO2 emissions is not the main focus of this research, although it is discussed in this document.

2 Research Methodology

In the previous sections, the research questions and scope were defined. In this section, I discuss what steps I will take in order to answer my main research question. I have split up the main research question into four sub questions, each consisting of one or more investigative questions. I should find an answer for each investigative question in order to find an answer to each sub question. Based on the answers to the sub questions, I will answer the main research question.

A number of steps should be taken in order to find an answer to all these questions. First, a *literature review* is going to be done. In this literature review, the most important theory in the field of carbon footprint calculations will be examined in detail. The literature review should provide an extensive understanding of how a carbon footprint can be calculated. Furthermore, it should provide knowledge on the required level of detail of a calculation, knowledge of how emissions can be allocated, knowledge of how uncertainty of the calculation can be assessed and knowledge of IT that can be used for the calculation, since these topics are all part of the research questions.

Second, an *analysis* will be done. In the analysis, I combine literature of the literature review with reports of universities that have already calculated their CO2 emission. While in the literature review, a few calculation methodologies for carbon footprint calculations will be described, in the analysis I will examine the relevance of a few commonly used standards to my research. Reports of universities will also be analyzed to define what CO2 emission categories are significant for universities. A reason to do this is that the standards that are discussed in the literature review are mainly focused on calculating GHG emissions in general, in terms of CO2 equivalents, instead of a CO2-specific calculation. Using the reports of universities, I can define what emission categories are significant for CO2 at universities specifically. The analysis of the literature and the reports should lead to an explanation of what emission categories should be present in a CO2-specific calculation for a university, in what scopes, and why these categories should be present. This can serve as an outline for the calculation that I will do for Erasmus University; a basic description of the model that I will use for calculating the carbon footprint of Erasmus University.

There are two main reasons for focusing on CO2-specific emissions. Most research in the past has focused on CO2 equivalents, rather than CO2-specific emissions. Therefore, doing a research focused on CO2-specific emissions can be a valuable addition to the scientific knowledge base. In addition, the choice was made to limit my scope. CO2 was chosen, because it is the most important source of GHG emissions.

Third, a *case study* will be performed. For the case study, the carbon footprint of the Erasmus University Rotterdam (EUR), location Woudestein, will be calculated. To do this, several steps will be taken. I will have to examine in more detail what data is exactly necessary to calculate the carbon footprint for Erasmus University Rotterdam. Then I have to gather all the data that is necessary for calculating the carbon footprint. Some data may have to be transformed into suitable activity data, if the required activity data for my calculation is not immediately available.

For calculating the carbon footprint, an Excel sheet is going to be used. In the Excel sheet, all the calculations will be visible. Five basic tasks have to be done to complete the Excel sheet:

- Preparing the data to be suitable for activity data
- Entering activity data
- Entering emission factors
- Entering rules for calculating the carbon footprint as a result of the entered activity data and emission factors
- Layout

There are several reasons for choosing to use Excel for the calculation. Limited time is available for the research. Therefore, using a common tool as Excel is easy. Second, it makes it easy to be transparent in the calculations, because all the formulas that are used for the calculations can be made visible. Third, my calculation is not a very advanced or difficult calculation. Therefore, calculation programs that are more advanced than Excel are not necessary.

Aside from all the calculations, other topics in calculating the carbon footprint are discussed in the case study. I will discuss different allocation possibilities. Furthermore, I perform a sensitivity analysis, which describes how certain CO2 emissions can change if the method of calculating the carbon footprint is slightly altered. In addition, I will do two interviews in the case study. These interviews are going to be done to get more information on the possibilities of introducing a more advanced system to calculate the carbon footprint at EUR:

1. An interview with Robbert Jacobs of SAP (the ERP system provider of Erasmus University Rotterdam)
2. An interview with Marcel Hoornweg, head of the Department SSC ICT Product Management at Erasmus University Rotterdam.

The case study should provide me with a better understanding of the current situation at EUR. It should give me more insights in how a model for calculating the carbon footprint should be designed. From the case study, I will get an idea about the required effort that is necessary to do the calculation, and I will get an idea of the difficulties calculating the carbon footprint of the organization. The practical knowledge that I will gain from the case study will be a valuable addition to the theoretical knowledge from the literature review.

After the case study, I discuss several topics that are directly related to my research questions. In the *discussion*, I will discuss whether the results from the case study, that are mostly specific for EUR, can be generalised to other universities. In this paragraph, it will become clear what changes could possibly be made to my model, in case of a subsequent calculation. Taking all the information of the literature review, analysis and case study together, I will discuss pros and cons and describe my own ideas on the several topics of interest that are directly related to my sub questions. After the discussion, I will summarize the main points that were already visible in the discussion and give my final answer to the different sub questions. Using the answers from the sub questions, I will answer my main research question.

To summarize my methodology: first a literature review will be done. Afterwards, an analysis will be done on the carbon footprint standards and universities' CO2 reports. After the analysis, I will apply my knowledge to the case study, where I calculate the carbon footprint of EUR and discuss other topics that relate to the calculation. Then, in the discussion the pros and cons are evaluated and my own opinion on certain topics is given. The results of the discussion are then used in the conclusions to summarize my answers to the research questions.

Research outline

In the remainder of this chapter, I describe how the research questions and methodology relate to the structure of this document. First, I will repeat the sub questions (without the investigative questions):

1. **How much detail should be included in CO2 administrations?**
2. **How should information be gathered, processed and presented?**
3. **How can emissions be allocated to the various objects that cause CO2 emissions?**
4. **How can differences between different organizations be incorporated into the model?**

Question 1 relates to which activities to include in the calculations. This is the topic of paragraph 3.3 in the literature review, paragraph 4.4 in the analysis, paragraph 5.2 of the case study and paragraph 6.2 of the discussion.
Question 2 is the most extensive question, which comes back in a large number of paragraphs, since the question comprises many different subjects. Question 2 is discussed in paragraph 3.4 and 3.8 in the literature review, paragraph 4.5 in the analysis, paragraph 5.3, 5.4 and 5.5 in the case study and paragraph 6.3 in the discussion.

Question 3 is a more specific question, which is discussed in paragraph 3.5 in the literature review, subparagraph 5.4.2 in the case study and paragraph 6.4 of the discussion. Question 4 is a question that does not specifically return in specific paragraphs, except for paragraph 6.5 in the discussion which is dedicated to question 4. The issue also is discussed in other chapters, but not in a specific paragraph.

There are other paragraphs that are not directly linked to one of the sub questions, but that comprise multiple sub questions. An example of such a paragraph is paragraph 3.8, in which literature about carbon footprints of universities is discussed. In addition, paragraph 4.2 and 4.3 also relate to multiple topics.

3 Literature review

3.1 Chapter Introduction

In the literature review, an overview is given of previous research in the field of calculating carbon footprints. This had to be done for two reasons: to gather information about the subject to do my own research and to know which topics have already been investigated in prior research.

For the literature review, various pieces of scientific literature are used:

- Literature about environmental accounting in general
- General literature about keeping track of CO2 footprints
- Literature about information systems required for calculating CO2 footprints.
- Literature about allocation of CO2 emissions
- Other literature

Furthermore, multiple sources are consulted for the literature review.

- Books
- Websites
- Scientific papers
- Reports of universities
- Standards

Three main methods have been used to find the necessary literature. First, a search was done for reliable standards in the field of carbon footprinting. The ISO 14064 standard was found first (ISO, 2006). This standard is about quantification and reporting of GHG emissions. The references of this standard led me to the GHG Protocol (WBCSD & WRI, 2003). The Campus Carbon Calculator was found in a paper about methods of estimating the carbon footprint (Pandey et al, 2011).

Second, Google Scholar was used to find several articles in the field of carbon footprinting. Search query's were done for each sub question. I began with searching for general articles about green accounting. After this, I started looking for literature about calculating the carbon footprint. Afterwards, I started searching for literature about specific topics in the field of carbon footprint calculations, such as literature about allocation of emissions and ICT for calculating the carbon footprint. Finally, I used the library database to look for books related to carbon footprint calculations.

In paragraph 3.2, an introduction to the topic of environmental accounting is given. Accounting for carbon emissions is part of environmental accounting. This introduction is useful to understand the context of accounting for carbon emissions, and to see how accounting for carbon emissions relates to other fields of research. Also, definitions of the "carbon footprint" are discussed, including the definition that I use in this research. It is important to clearly state the definition of the carbon footprint, to avoid confusion about what the term actually means. In paragraph 3.3, possible emission sources are discussed. This is necessary to decide what emissions to account for in my own model for universities. In paragraph 3.4, ways of collecting and processing the data to calculate carbon footprints are discussed. This is the most important part of the literature review, as calculating carbon footprints is the main topic of this research. Information systems are also discussed in this paragraph.

Allocation is also a topic of my research. Among other things, this research aims to determine a proper way of allocating carbon dioxide emissions to education and research of a university. Therefore, allocation is discussed in paragraph 3.5. In paragraph 3.6, special situations that could possibly affect carbon footprint calculations are discussed. Paragraph 3.7 discusses ways of verifying the quality of the data for calculating the carbon footprint. Finally, paragraph 3.8 discusses literature that is specific to calculating the carbon footprint for universities.

3.2 Introduction to environmental accounting

3.2.1 General theory about environmental accounting

Burritt et al. compare environmental accounting to conventional accounting. There seem to be many similarities between the two. Conventional accounting can include physical data as well as monetary data. Although people usually think of monetary values when thinking of accounting, physical data are also an important part of conventional accounting. Examples of systems that incorporate such data are production planning systems, inventory accounting systems and quality systems. In addition, physical data forms the basis for many of the monetary values.

In traditional accounting, a distinction is also made between management accounting and financial accounting. Management accounting is there to support management to make certain decisions. For example, sales data is used to make certain decisions about optimal quantities that should be produced. While management accounting has an internal focus, financial accounting has an external focus. Financial accounting is used for communicating to certain stakeholders. Legal requirements are one reason to use financial accounting. Depending on the company, some reports are required by law (Tutor2u, n.d.; Burritt et al, 2002). Financial accounting is also used to report to other stakeholders than government, like banks and other investors, media, customers, potential employees and partners, and interest groups like NGOs and local communities.

A parallel can be made between conventional accounting and environmental accounting (although Burritt et al. (2002) do not entirely approve of the term “conventional accounting”). Both physical data and monetary data are areas of interest in environmental accounting. Additionally, just like with traditional accounting, different stakeholders are interested in different types of information. Within the company, at the production department, there is a need for environmental data related to production to minimize environmental impacts and financial costs that arise from these. This would be a type of environmental management accounting. The environmental accounting framework of Burritt et al (2002) is displayed by figure 3 below:

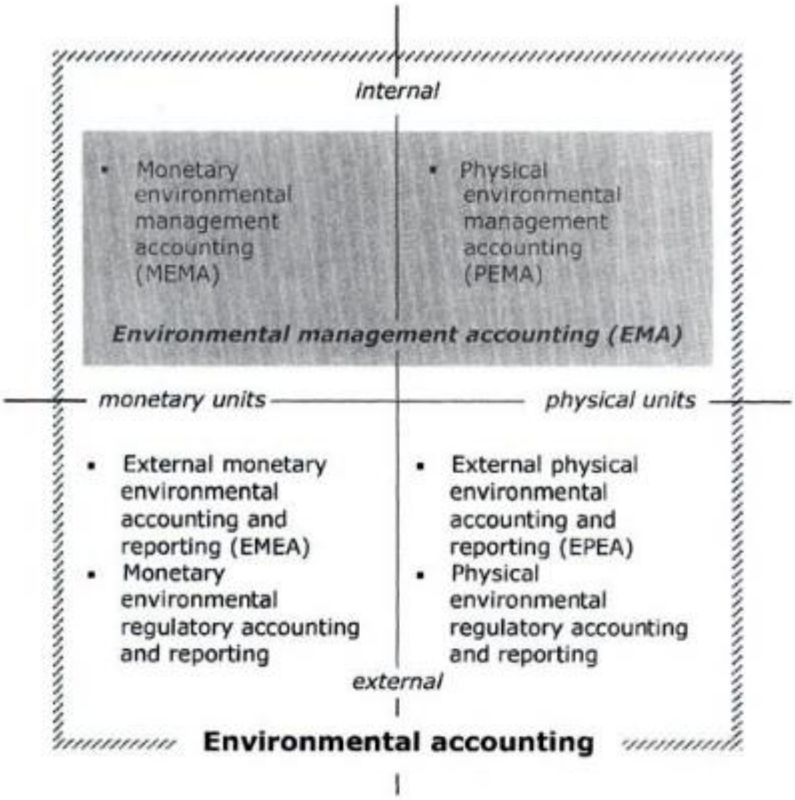

Figure 1: Integrative framework of environmental accounting (Burritt et al, 2002)

In this framework, multiple types of environmental accounting can be found. A distinction is made between internal and external environmental accounting. There is a distinction between physical and monetary environmental accounting. Different parts of the framework can be related to each other. For example, physical data can sometimes be converted to monetary data. If a company has to pay taxes when they have a certain amount of CO2 emissions, then CO2 emission data could be converted to monetary data. Therefore, the framework of Burritt et al. (2002) provides a distinction between monetary and physical data, but also "provides an overarching structure to relate the different parts of environmental accounting".

Perrini & Tencati (2006) discuss a sustainability evaluation reporting system (SERS). The paper by Perrini & Tencati is relevant for this research, because it deals with the connection between sustainability reports (including the environmental report) and information systems. The structure of the environmental report in the SERS is based on the framework of Burritt et al. (2002). The SERS can be used to assess and report about corporate sustainability in a company. Using the model, companies can find which improvements could be needed to improve their corporate sustainability. The model consists of multiple components. These components can be found in the figure below:

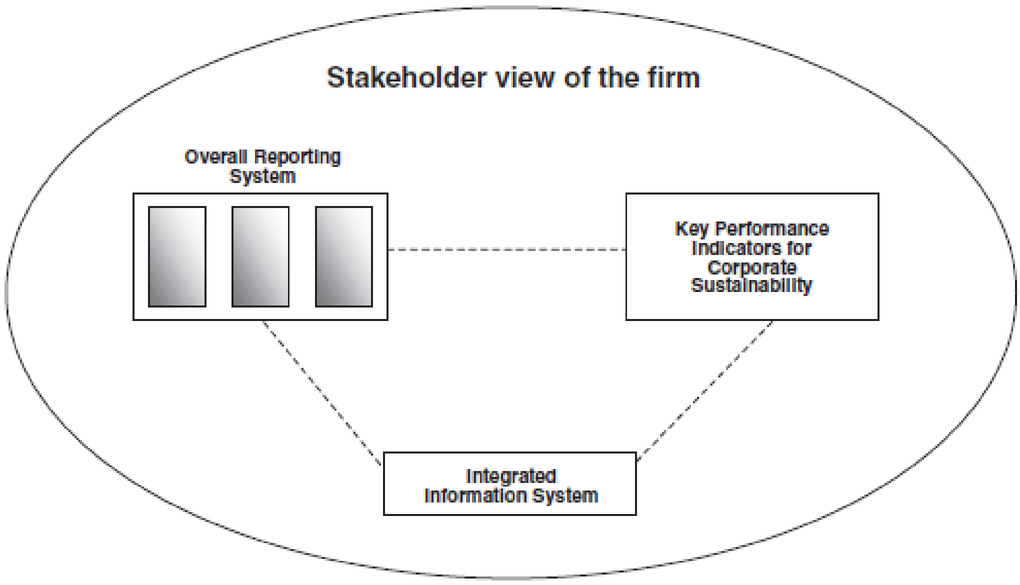

Figure 2: The sustainability evaluation and reporting system (Perrini & Tencati, 2006)

The system consists of three main components that all interact with each other. There is an overall reporting system present, consisting of an annual report, social report, environmental report and a set of integrated performance indicators. Second, key performance indicators (KPIs) for corporate sustainability have to be present. Third, integrated information has to be present to be able to collect, process and share relevant data.

Data can be both financial and technical data. The set of integrated performance indicators should include a way to combine technical, non-financial, physical data with financial data; cross-cutting indicators should be present to give an integrated and complete picture of the corporate activities and implications of these activities. As an example of such cross-cutting indicators, Perrini & Tencati (2006) talk about "e.g. an indicator could relate the total amount of waste generated during the year to the value added". I believe similar things can be done for CO2 and a university. For example, the total amount of CO2 generated during the year could be related to the value added.

Perrini & Tencati (2006) state that the integrated information system is "the core of performance evaluation and reporting processes". The integrated information system should enable the gathering, processing and reporting of data (both financial and technical data). The system can be based on technologies like ERP (Enterprise Resource Planning). It should be connected to other accounting/information systems in the organization. This can enable the decision makers to collect and distribute the desired information to be able to assess sustainability and overall performance of a company.

Perrini & Tencati (2006) talk about the environmental report as "a tool a company uses to manage and control corporate activities and support communication with stakeholders, especially those interested in environmental issues". The corporate environmental report can be split into two major categories: energy and materials accounting, and monetary environmental accounting. More about both categories of the corporate environmental report can be found in the next subsection. A figure that displays the structure of the environmental report can be found below:

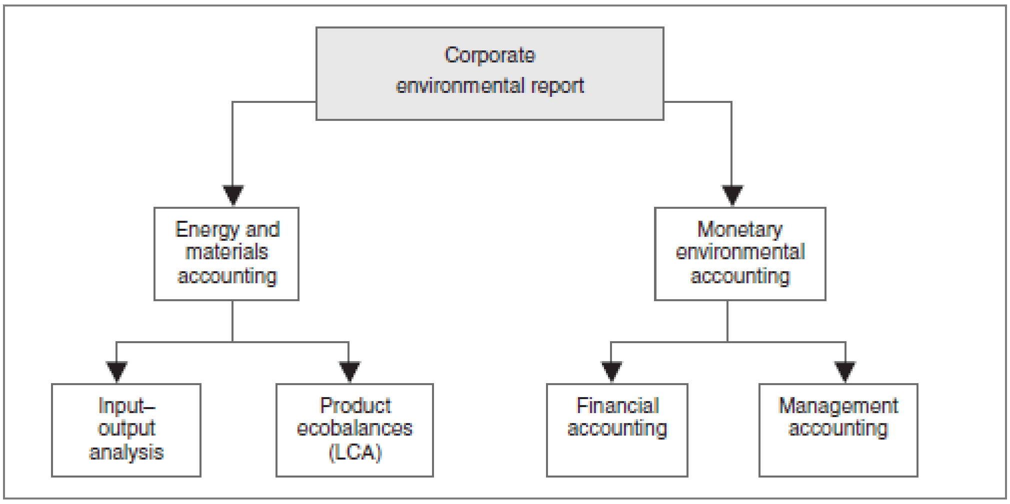

Figure 3: The corporate environmental report in the SERS model (Perrini & Tencati, 2006)

In this subsection, a general overview of environmental accounting has been given. Environmental accounting comprises both non-monetary environmental accounting and monetary environmental accounting. Both of these terms are discussed in more detail below. This research mainly emphasizes on carbon footprints. This is a part of non-monetary environmental accounting. Therefore, non-monetary environmental accounting is discussed in a bit more detail in the next subsection.

3.2.2 Non-monetary environmental accounting

In the SERS model of Perrini & Tencati (2006), non-monetary environmental accounting is present as one of the two parts of the environmental report. In this model it is called "energy and materials accounting". Two different parts of energy and materials accounting can be distinguished in the model. The first part is input-output analysis. Input-output analyses "gather and organize the information on energy and material consumptions and the related emissions caused by the operations" (Perrini & Tencati, 2006). Second, ecobalances (LCA) measure resource consumption and pollution of main products of the firm along their life-cycle.

Keeping track of the carbon footprint is one way to keep track of non-monetary environmental data. My research is about carbon footprints. Therefore it would be useful to discuss a few definitions of "carbon footprint". As said before in the introduction, carbon footprint can be defined as "a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann and Minx, 2007). Carbon Trust (2007) defines the carbon footprint as "a technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain process step and the framework for attributing these to each output product". Environmental Technologies Action Plan (ETAP, 2007) states that "the 'Carbon Footprint' is a measure of the impact human activities can have on the environment in terms of the amount of greenhouse gases produced, measured in tonnes of carbon dioxide".

Greenhouse gas emissions are often measured in kg CO_2 or kg CO_2e. There is an important difference between these two units. The unit "Kg CO_2" only deals with the weight of the carbon dioxide emissions. The unit "Kg CO_2e" (kg carbon dioxide equivalents) is a number that also incorporates greenhouse gases like CH_4 and N_2O. The global warming potential (GWP) indicates the degree of harm to the environment of a unit of a certain greenhouse gas relative to CO_2 (WBCSD & WRI, 2003). This number can be used to calculate the emission in terms of CO_2 equivalents (CO_2e). For example: if 20 kg CO_2 and 0,5 kg of CH_4 is emitted, and the GWP of CH_4 is 21, then the CO_2e emission is 20 + 0,5 * 21 = 30,5 kg.

The carbon footprint definition that I use is the definition by Wiedmann & Minx (2007). The reason for this is that I focus on carbon dioxide rather than GHG emissions in general.. Furthermore, it is a very broad definition, which is suitable, because many sources of emissions can be accounted for by making use of carbon footprints.

3.3 Types of emissions and activities that can cause emissions

ISO 14064 (2006) classifies greenhouse gas (GHG) emissions into different types: direct GHG emissions and removals, energy indirect GHG emissions and other indirect GHG emissions. A direct greenhouse gas emission is defined as a "GHG emission from greenhouse gas sources owned or controlled by the company". An energy indirect greenhouse gas emission is defined as a "GHG emission from the generation of imported electricity, heat or steam consumed by the organization". An other indirect GHG emission is defined as a "GHG emission, other than energy indirect GHG emissions, which is a consequence of an organization's activities, but arises from greenhouse gas sources that are owned or controlled by other organizations" (ISO, 2006).

The Greenhouse Gas Protocol (GHGP) talks about the same categories as ISO. Operational boundaries can be defined by companies on what emissions to include in the assessment. Emissions can be categorised into scope 1 (direct GHG emissions), scope 2 (electricity indirect GHG emissions) and scope 3 (other indirect GHG emissions). Scope 1 and 2 are mandatory for companies to be compliant with the standard (WBCSD & WRI, 2003). Different types of emissions can be attributed to these three different scopes. The following emissions are emissions of scope 1 (WBCSD & WRI, 2003):

- Generation of electricity, heat or steam
- Physical or chemical processing
- Emission resulting from combustion of fuels in company owned/controlled mobile combustion sources that are used for transportation of materials, products, waste and employees.
- Fugitive emissions. These fugitive emissions are the result of certain emission releases of the organization, like air-conditioning or refrigerators

Scope 2 contains purchased electricity, which is used as "shorthand for electricity, steam and heating/cooling". Scope 3 contains the following activities according to the GHGP (WBCSD & WRI, 2003):

- Extraction and production of purchased materials and fuels
- Transport-related activities
- Electricity-related activities not included in scope 2
- Leased assets, franchises and outsourced activities

- Use of sold products and services
- Waste disposal

When looking at scope 3, similar things are listed as in scope 1. The difference between scope 1 and 3 is that scope 1 is about emission sources that are owned by the company, and scope 3 is about emission sources that are not owned by the company. Reporting scope 3 emissions is not mandatory according to the GHG Protocol (WBCSD & WRI, 2003). Furthermore, some emission sources may be present in both scope 1 and scope 3. For example, scope 1 emissions include emissions from combustion of fuels in cars, while scope 3 includes emissions of the production of purchased fuels that may be used for cars (WBCSD & WRI, 2003).

Transport-related activities are a very important source of CO2 emissions for universities. The GHG Protocol (WBCSD & WRI, 2003) provides some more explanation about this category. The following activities in scope 3 are transport-related: transportation of purchased materials or goods, transportation of purchased fuels, employee business travel, employees commuting to and from work, transportation of sold products and transportation of waste. The “waste disposal” category (which may also be relevant to universities) can include waste of operations, waste of production of purchased goods and waste of disposal of sold products (WBCSD & WRI, 2003).

The distinction between direct and indirect emissions is an important distinction. One company may report a certain emission under direct emissions (scope 1), while another company might attribute the same emission to indirect emissions (scope 2 or 3). For example, an electricity company is the company that produces 100 MWh of electricity, emitting 20 tons of emission. The 20 tons of emission that is the result of the produced electricity is then reported under scope 1, because that is where “generation of electricity, heat or steam” belongs according to the GHGP. The produced electricity is then traded to go to a utility company. This utility company uses 5 MWh of electricity in its T&D (transmission & distribution) system, which is responsible for 5% of the emissions of the total amount of produced electricity, 1 ton. These emissions can be reported under scope 1. The remaining 19 tons of emissions can be reported under scope 3, because 95 MWh (95% of the total) is transferred to the end user that uses the 19 tons of electricity. The end user can then report 19 tons of emissions for the used electricity under scope 2, and 1 ton, the electricity lost in the utility company’s T&D system, to scope 3. This example is provided in the document of the GHG protocol (WBCSD & WRI, 2003). They also provide the following visualisation of the problem:

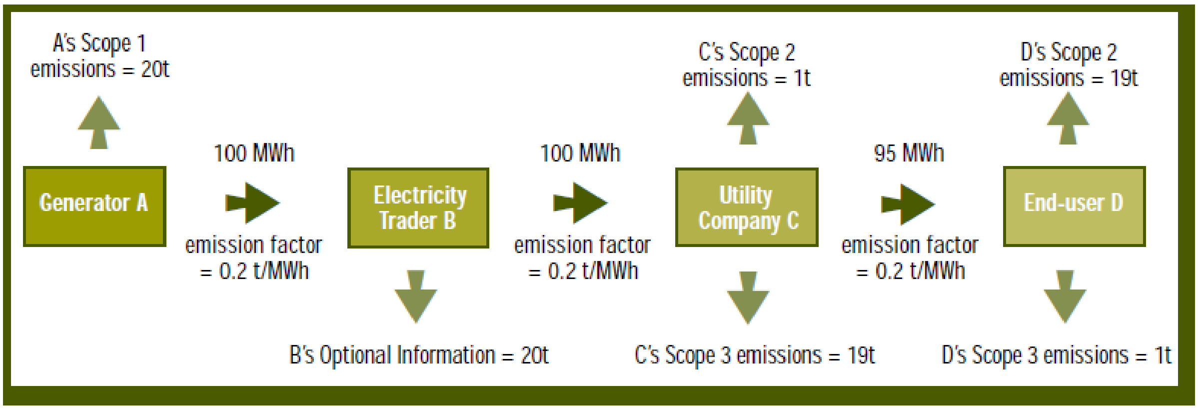

Figure 4: GHG accounting from the sale and purchase of electricity (WBCSD & WRI, 2003)

When looking at this example, it becomes clear that the total emission of 20 tons can be reported three times in three different companies: 20 tons in scope 1, 20 tons in scope 2 and 20 tons in scope 3. Emissions can be reported multiple times. However, emissions cannot be reported more than once in the same scope. So if all of the organizations in this example would be compliant with the GHG Protocol, then it would not be possible to report more than 20 tons to scope 3 in total.

This paragraph provides a clear picture of what emission sources and types of emissions can be accounted for when calculating a carbon footprint. A categorisation of emissions is given, divided in three scopes. It gives a good basis to understanding what data can be collected for calculating carbon footprints. Collection and processing of data is further discussed in the next paragraph.

3.4 Collecting and processing of information

This paragraph is divided into multiple sub-paragraphs, because collecting and processing is a big topic that has multiple different aspects to it. In 3.4.1, different ways to collect and process data for assessing carbon footprints are discussed. An introduction is given to two of the most important standards for assessing carbon footprints. In 3.4.2, the actual calculations necessary for calculating a carbon footprint are discussed. Sub-paragraph 3.4.3 discusses information systems that can be present in a company for supporting environmental accounting and, more specifically, calculating carbon footprints.

3.4.1 Ways to collect and process data

According to ISO 14064 (2006), three different methodologies of quantifying greenhouse gases (GHGs) can be used: calculation, measurement and a combination of calculation and measurement. Measurement can either be continuous or intermittent. Calculation can be based on the following things (ISO, 2006):

- GHG activity data multiplied by GHG emission or removal factors
- the use of models
- facility-specific correlations
- mass balance approach

According to Schaltegger & Burritt (2000), an environmental information system is very important. A way to do environmental accounting is to do a life-cycle assessment (LCA). LCA calculates the physical impact of a product, service, activity, infrastructure or process on the environment. LCA tries to capture all the environmental interventions or the environmental impact added during the entire life-cycle.

Schaltegger & Burritt (2000) also discuss the difference between collecting data from all parts of the value chain and using background inventory data. Using background inventory data means using standard data that relate an amount of a certain product to the impact on the environment. For example, tables could be available on the emissions of a kilogram of plastic. It is usually much cheaper for companies to calculate their emissions based on the inventory data and (for example) the amount of plastics that they use. However, using inventory data results in an estimation, rather than more detailed, specific information on the life-cycle. For example, information could be gathered on how the plastics are made. Emissions of each process that is necessary for creating the plastics can be calculated and added up to calculate the total emissions of an amount of plastics.

Collecting specific data for each stage of the life-cycle can be hard. If one company is doing the life-cycle assessment, then data from other companies is necessary as well. Different companies should cooperate to be able to make a good assessment of the total environmental impact of a product. Suppliers, producers and customers should cooperate in such a situation. In addition, the government has the power to create incentives for companies for doing environmental accounting. This could be used to promote LCAs to assess the environmental impact of a product (Schaltegger & Burritt, 2000).

PAS 2050 (BSI, 2008) is a standard that calculates the carbon footprint of products. The carbon footprint is here more broadly defined as the amount of greenhouse gas emissions, instead of the amount of CO2 emissions (which is the way it is defined in my research). The Greenhouse Gas Protocol, often abbreviated as the GHG Protocol, (WBCSD & WRI, 2003) is a more general standard for calculating the carbon footprint of an entire organization. In this case, carbon footprint deals with the emission of the six greenhouse gases that are covered in the Kyoto protocol. When I use the term “carbon footprint” while not talking about one of these two standards, then I am talking about carbon footprint as it is defined by Wiedmann & Minx (2007): “a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product”. When I talk about the term carbon footprint when describing these standards, then I am talking about the way in which one of these standards define “carbon footprint”. PAS 2050 and the GHG Protocol could be used together, depending on the level of detail that someone desires. The carbon footprint of an organization should be the sum of the footprints of each of the individual services and products that the company uses, produces and/or sells.

This paragraph has given a basic overview of possible ways to quantify a carbon footprint. PAS 2050 and the GHG Protocol are discussed in more detail in the next paragraph, as they both provide detailed information and steps to calculate the carbon footprint. Direct measurements of CO2 emissions by using certain measurement equipment are not discussed; such a method is not suitable for universities due to the nature of their emissions.

3.4.2 Calculations

ISO (2006) does not give much information about the actual carbon footprints calculations . Standards like the GHG Protocol (WBCSD & WRI, 2003) and PAS 2050 (BSI, 2008) go into more detail on this topic.

Two basic types of data are necessary to calculate the CO2 emissions of a company or product. First, activity data is necessary which provide more detailed information on the activities that lead to emissions. Examples of activity data can be the amount of gasoline used in a certain time frame (in litres), or the amount of paper consumed (in kilograms). Emission factors can be used to convert activity data to CO2 emissions. Emissions can be expressed into CO2 emitted per unit of measurement (kg / km / l / etc). For example, an emission factor could state the amount of CO2 that is emitted per kilogram of paper. Emission factors are source specific. This means (for example) that emissions of electricity produced by coal will be different from emissions of electricity produced by nuclear power. In general, this is the formula for calculating an emission (WBCSD & WRI, 2003; BSI, 2008; Carbon Trust & Crown, 2008; Putt del Pino & Bhatia, 2002):

CO2 emission = Activity data (kg / km / litres / etc) * Emission factor (CO2 per unit).

For both activity data and emission factors, a distinction can be made between primary data and secondary data. Primary data are direct measurements within the life cycle of a specific product. For example, the amount of litres of gasoline used per number of kilometres can be directly measured. Secondary data consists of external, averaged data, which are not specific to the product (Carbon Trust & Crown, 2008).

PAS 2050

When calculating the carbon footprints of products, the first step is to create a process map, according to the guide to PAS 2050 (Carbon Trust & Crown, 2008). A process map is a map that contains all of the different processes, materials and activities of the product's life cycle that could possibly result in emissions. The life cycle for business-to-consumer (B2C) is different than for business-to-business (B2B). For B2C, the life cycle is the entire process from raw materials to disposal and/or recycling. For B2B, the cradle-to-gate approach is used, meaning that the life cycle stops at the moment where the product or service is delivered to a different organization. For the life-cycle of services, an activity-based assessment is used; the life-cycle of a service contains any stage and emission source contributing to the delivery or use of the service to the customer (Carbon Trust & Crown, 2008).

The second step is defining the boundaries of the analysis. The system boundary "defines the scope for the product carbon footprint, i.e. which life cycle stages, inputs and outputs should be included in the assessment (Carbon Trust & Crown, 2008). According to PAS 2050, if a Product Category Rule (PCR, an internationally accepted rule that defines the product's life cycle) is available, then this rule should be used to define the product's life cycle. PAS 2050 includes several exceptions that state what should not be included in the analysis. For example, employees travelling from and to work should not be included in calculating the carbon footprint of a product (BSI, 2008).

Collecting the data necessary for calculating the carbon footprint is the third step. Data should be relevant, complete, consistent, accurate and transparent according to PAS 2050 (Carbon

Trust & Crown, 2008). Activity data and emission factors are, as discussed before, the data that is necessary for calculating the carbon footprint.

The fourth step is the actual calculation of the footprint. According to PAS 2050, "the equation for product carbon footprinting is the sum of all materials, energy and waste across all activities in a product's life cycle multiplied by their emission factors". So activity data should be multiplied with the emission factors for all activities, and then all of these calculated CO2 emissions should be added up. Just as Schaltegger & Burritt (2000) state, total mass of the input of all the materials should equal the total mass of the output (Carbon Trust & Crown, 2008). The process map should be used as guidance for the calculation of the footprint of a product, which splits the whole life-cycle of the product into small steps. For each step, the carbon footprint should be calculated, and carbon footprints of each step should be added up to get the total carbon footprint of a product.

Several special cases can occur when calculating carbon footprints, for example cases of a changing supply chain, sampling, recycling and renewable electricity. In addition, PAS 2050 excludes capital goods, aircraft emissions uplift factor and offsets from the carbon footprint.

Greenhouse Gas Protocol (GHGP) A big difference between the Greenhouse Gas Protocol (WBCSD & WRI, 2003) in relation to PAS 2050 is that the GHGP deals with the carbon footprint of organizations rather than products or services. Just like PAS 2050, the GHGP provides a number of steps to assess the carbon footprint:

- Identify GHG emissions sources
- Select a GHG emissions calculation approach
- Collect activity data and choose emission factors
- Apply calculation tools
- Roll-up GHG emissions data to corporate level

First, emission sources have to be identified, which can be categorized into scope 1, scope 2 and scope 3 emissions. Putt del Pino & Bhatia (2002) provide an additional explanation of activities that can be included in the assessment, specifically for office-based organizations. Combustion of fuel in boilers and furnaces can be included in the assessment (in scope 1 or 3, depending on the organization that is the owner of the boilers and furnaces). In scope 1, business travel and commuting in company-owned vehicles is included. Scope 3 also includes "incineration of office waste or decomposition in a landfill when the facilities are not owned by the reporting organization" and emissions of outsourced activities.

After the identification of emission sources, a calculation method should be chosen. The GHG Protocol is not very specific about which calculation methods organizations can use. Calculation methods can range from using direct monitoring to using generic emission factors. Each organization should choose what is most appropriate for them. Third, activity data has to be collected and emission factors have to be chosen by the organization. More can be read about this step in paragraph 3.4.3.

Fourth, calculation tools have to be used. Just as with PAS 2050, emissions can be calculated by multiplying activity data with emission factors. A number of calculation tools for specific sectors can be found on the GHGP's website. Organizations can use one or more calculation tools to calculate their carbon footprint. The last step in calculating the carbon footprint of an organization, in the case of using the GHG protocol, is rolling up the GHG emissions data to the corporate level. Data can come from different sources. Therefore, data from all parts of the organization should be taken together to calculate the total carbon footprint.

For accounting of scope 3 emissions specifically, the GHG Protocol (WBCSD & WRI, 2003) also describes a number of steps. According to WBCSD & WRI (2003), it is not necessary to do an entire life cycle analysis of all operations and products. Some general steps are described by WBCSD & WRI. First, the organization should describe the value chain and its GHG sources. Organizations also have to decide how many levels of the value chain they will include in their analysis. Second, the organization should determine which possible scope 3 emission sources are relevant to the organization. Third, organizations should identify the most important parties in the value chain. The most significant GHG emitting organizations in the value chain should be identified. Fourth, scope 3 emissions are quantified.

In this subparagraph, the GHG Protocol, PAS 2050 and literature about these standards have been discussed. The GHG Protocol and PAS 2050 both describe a number of steps to calculate the carbon footprint. For both standards, the footprint is calculated by summing up multiplications of activity data with emission factors. Deciding the scope of the calculations, collecting data and doing the actual calculations are steps that are described in both standards. Some steps are different between the two standards. A suitable explanation for this is that the standards are created for different reasons; the corporate GHG protocol is useful for the carbon footprint of organizations, whereas PAS 2050 should be used for calculating the carbon footprint of products or services. In the next paragraph, data sources and information systems are discussed. Data sources are absolutely necessary for calculating a carbon footprint. Information systems are discussed, because IT is very important for gathering the data and doing the actual calculations.

3.4.3 Data sources and information systems

According to Carbon Trust & Crown (2008), engaging suppliers is very important for gathering data and for understanding the life cycle of a product. Organizations usually have good knowledge about the production process of their own organization. However, often not as much knowledge exists of other companies' processes. Therefore, it is important to talk to other organizations in the life cycle of a product, when collecting data for calculating the carbon footprint of a product.

Two types of data can be distinguished according to PAS 2050: primary data and secondary data (Carbon Trust & Crown, 2008; BSI, 2008). These concepts were discussed in paragraph 3.4.2. According to the guide to PAS 2050, primary activity has to be used "for all processes and materials owned, operated or controlled by the footprinting organisation" (Carbon Trust & Crown, 2008). There is an exception though. If the organisation's own processes and materials count for less than 10% of the total upstream GHG emissions, then this primary data requirement is required for the emissions of the closest upstream supplier that contributes to 10% or more of the upstream GHG emissions (BSI, 2008).

Primary activity data can be gathered internally or by using a third party. Using primary data is usually best for the quality of the data, because data will then be specific for a certain product's life cycle. If the quality of primary data is insufficient, or if primary data is unavailable, secondary data has to be used which can be gathered from databases. Many databases are available that can be used, e.g. multi-sector life cycle databases, industry-specific databases or country-specific data sources (Carbon Trust & Crown, 2008).

The Greenhouse Gas Protocol (WBCSD & WRI, 2003) talks briefly about ways to collect the data necessary for calculating the carbon footprint. For activity data, organizations can often just use the purchased quantity of a product. For example, organizations can monitor fuel use or monitor the metered electricity consumption. Emission factors are often factors that are published elsewhere. Organizations should try to use emission factors that are as specific as possible. After collecting the data, calculations have to be done, for example by making use of Excel-sheets. When the different calculations in an organization are done, then the GHG emissions data are rolled up to the corporate level. Data from multiple places is gathered and added up to get the total carbon footprint of an organization.

The chosen tools and processes for reporting data depend on the existing ICT infrastructure of the company. For example, it can depend on the degree to which it is easy to include new data in databases. The chosen tools and processes also depend on the desired level of detail reported from the organization's facilities. Reporting formats should be standardized within the organization. This should be done to ensure comparability between data received from different business units and facilities. In addition, internal reporting rules should be observed (WBCSD & WRI, 2003).

A number of data and collection and management tools can be used, including (WBCSD & WRI, 2003):

- Secure databases available on the company intranet or internet. Divisions can use this to directly fill in data.
- Spreadsheet templates filled out and e-mailed to a corporate or division office. This office can then process the data.
- Paper reporting forms faxed to a corporate or division office. Data is then re-entered into a corporate database at such an office. There should be sufficient checks present to ensure that the data that is entered into the database will be accurate.

Putt del Pino & Bhatia (2002) elaborate the possible sources of data for calculating the carbon footprint of office-based organizations, that do not undertake any manufacturing activities. For some emission sources, the way of collecting data is discussed. In scope 1, information can be retrieved from fuel-usage records of the company. For scope 2, for electricity, activity data can be obtained from monthly electricity bills.

For scope 3, gathering data is a bit more complicated. For car travel in company-owned vehicles, activity data can be gained from fuel use receipts. Additionally, there should be data on how many people were in the car. Only the part of the fuel allocated to the organization’s employees should be attributed to the organization. Activity data for train and air travel consists of the amount of kilometers traveled. Distance of the flights can often be found at flight itineraries or at guides on websites. Distance of a train can be found in a similar way.

When employees are commuting in non-company owned vehicles, getting reliable fuel-use data for commuting can be a bit harder. For a non-company owned car, employees are unlikely to use the car only for commuting. Therefore, calculations have to be done about the amount of kilometers driven while commuting, to be able to calculate the estimated fuel use that can be attributed to the company. Of course, these types of information are not always available. Sometimes data has to be calculated. For example, if fuel use data of a car is not available, then calculations have to be done. Fuel use can be estimated when knowing the distance traveled and the average fuel efficiency of the car.

Aside from activity data, emission factors also have to be gathered. Various sources are available for this. The GHG Protocol's website (www.ghgprotocol.org) provides several emission factors that are often updated. The Intergovernmental Panel on Climate Change (IPCC) also publishes frequently updated emission factors (Putt del Pino & Bhatia, 2002).

Busch et al. (2006) refer to Rikhardsson (1998), who describes four approaches to integrating environmental data with the IT infrastructure in a company. The existing IT (information technology) infrastructure is one strategy that can be used for this. Second, a new Environmental Management Information System (EMIS) could be designed. Third, an existing corporate information system (IS) could be re-engineered. Fourth, a standard system package could be implemented.

Hammarström (2010) wrote a paper about ERP and environmental footprint management for manufacturers. He claims that data on the impact of certain operations on the environment is usually difficult or impossible to get. Appropriate IT is not available to collect the necessary data. Furthermore, data originates from many different places in the organization. There should be a flexible environmental program in the company, which is enabled by enterprise software. This requires a tight integration between environmental functionalities and ERP (Enterprise Resource Planning) systems. Most of the environmental data is present within these systems (Hammerström, 2010).

A survey done by IFS indicates that executives in manufacturing companies are often not satisfied with the capabilities of ERP systems with regard to environmental management. 48 percent of the managers said they could not measure environmental impact with their ERP system. Furthermore, only 7 percent of the interviewees had an ERP system with comprehensive capabilities for environmental impact assessment. Some ERP systems do not even have a component which can measure environmental impacts. Therefore, some of the vendors of these ERP systems acquired companies that created carbon footprint solutions to be able to offer separate packages for environmental management to the customer. These packages often require an expensive integration project to be able to cooperate with other systems.
Because of the lack of suitable environmental management functions in ERP software, many companies are using tools with limited capabilities like Microsoft Excel spreadsheets. These kinds of tools require more manual interventions, which makes it harder to integrate environmental data with other data that is present in the company (Hammerström, 2010).

Almost everything in an organization has both a cost component and an environmental component. Therefore, having an environmental management system that is completely unconnected from the rest of the organization is not going to make it easy to measure environmental impacts. Just as with costs, environmental data can be managed in a centralized way by making use of ERP. ERP is a system that stores data from many different parts of the company. Therefore, it makes sense to gather environmental data in an ERP system. Furthermore, using the system can be easier when users only have to learn how to use one system, instead of two systems. There are certain requirements for environmental management tools. It should be possible to track environmental impacts like tracking costs. There is much data available for keeping track of costs. An environmental footprint management solution should make use of this cost accounting system. Environmental impacts occur at the same types of activities that involve costs. Another requirement is the connection with the supply chain; manufacturers need to have data available on raw materials and the environmental impacts of acquiring these materials. In addition, the software solution should be able to keep track of emissions of the manufacturer's own processes (Hammerström, 2010).

The paper by Lambert et al (2000) also deals with the integration of environmental information within ERP systems. Lambert defines ERP tools as "integrated software controlling logistics, cost accounting, and other features relevant to production systems". ERP integrates many business activities in a company. Therefore, ERP systems are created from a different point of view than environmental information systems, because the latter are more like isolated software tools (Lambert et al, 2000).

Möller et al. (2006) wrote a paper about computer support for environmental management accounting (EMA). According to them, there are three direct requirements for EMA computer applications: data collection, data processing and data supply. EMA should implement instruments like materials flow accounting and should develop a database. Möller et al. (2006) also discuss ERP systems. ERP systems contain financial and non-financial data that can be essential for EMA. Necessary data for EMA systems should be able to be retrieved from ERP systems. However, EMA requirements are not always met in data models and structures of common business information systems (Möller et al, 2006).

Two approaches can be distinguished for developing a computer based environmental management IS. One possibility is to integrate the EMA application in the current, existing ERP system. Although this integration does have certain benefits, integration can be hard, because other parts of the ERP system may have to be adjusted in that case. Another possibility is to have a stand-alone EMA system (Möller et al, 2006).

This subparagraph focused on data sources and the application of ICT to collect and process data. Activity data and emission factors have to be gathered and processed to result in a CO2 calculation. Activity data is usually present at the organisation itself (i.e. data about car kilometres, electricity usage, etc.), but may have to be gathered elsewhere; it may be collected by contacting other organisations in the value chain, by contacting third parties or industry-averaged data can be used as activity data. Emission factors are usually published somewhere on the web for a certain industry. Using specific emission factors that are directly related to a certain process is also possible, but takes more effort to obtain, if possible at all. Once data is present somewhere in the organization, it has to be processed for the CO2 calculation. For this purpose, the data has to be transferred to the right place. This can be done in multiple ways: directly filling in data in databases, filling in spreadsheet templates or, preferably, having a connection between an environmental management system and an ERP system to transfer the data directly, because an ERP system often stores a lot of information that can immediately be used as activity data. An ERP system can sometimes even measure environmental impacts itself.

If an ERP system transfers data to an environmental management system, then integration of the two systems is important to ensure that data can be exchanged between the two systems. In the next paragraph, allocation is discussed. This is a topic that can add extra complexity to calculations.

3.5 Allocation of emissions

WBCSD & WRI (2010) define allocation as "the process of partitioning GHG emissions from a single facility or other system among its various outputs". In my research, I will try to make a distinction between emissions for research and for education. However, some resources are shared by education and research. For example, certain buildings are used for both education and research. Therefore, there has to be a way to allocate certain emissions to certain activities. This is what will be discussed in this paragraph.

3.5.1 Control and equity share

ISO 14064 (2006) states there are two approaches for allocation of GHG (greenhouse gas) emissions, which are in fact two approaches for setting organizational boundaries: control and equity share. Consolidation based on control means that the organization accounts for all of the emissions that are under their control. The organization does not account for emissions that are not under their control, even if the organization would have an interest in the operation that causes the emissions. Control can be defined in two ways: financial control or operational control.

The organization that is financially in control is the organization that can direct financial and operating policies of an operation to gain financial benefits from the activities. This organization is the organization that keeps the risks and rewards of ownership of the assets of an organization. The organization that is operationally in control is the organization that has the rights to "introduce and implement its operating policies on the organization" (WBCSD & WRI, 2003).

Consolidation can also be based on equity share. When organizations share a certain facility that emits GHG(s), then an ownership percentage can be calculated for each organization that shares the facility. CO2 emissions could then be attributed to each company, depending on the ownership percentage of each company (ISO, 2006; WBCSD & WRI, 2003).

3.5.2 Allocation of scope 3 emissions

The GHG Protocol Initiative is currently busy with developing a corporate standard for GHG emissions of scope 3 (WBCSD & WRI, 2010). In their provisional document, much information is provided about allocation. The focus of the document is on scope 3 emissions, but I believe this theory can be used to cover other types of emissions as well. In this document, allocation is defined as "the process of partitioning GHG emissions from a single facility or other system among its various outputs". Allocation should be used when multiple products or services are produced in one facility and emissions are only measured for the entire facility.

If avoidance of allocation is not possible, then allocation should be used. First, the emissions of the total system or facility should be determined. After this, a proper allocation method should be chosen. A method should be chosen that is most close to reality. It should reflect the causal relationship between the outputs and the emissions in the best possible way. For example, WBCSD & WRI (2010) state that physical methods of allocation are most suitable for allocations of emissions of commercial buildings.

There can be physical allocation, economic allocation and other methods of allocation. Physical allocation involves allocating emissions based on some physical aspect(s). For example, allocation to a certain organization that buys products could take place based on an organization's share of mass or volume in the supplier's production process. Economic allocation can be done, based on the market value of a product. Furthermore, organizations can use sector-specific or company-specific allocation methods. Companies should first check if a physical method of allocation can be used before considering using an economic or other method of allocation. A combination of allocation methods can be used for the different types of emissions in scope 3, as long as allocation methods used for an entire system or facility as a whole are consistent for each individual facility or system.

When the total emission is calculated for a certain emission source of the university, then the carbon emissions of that source can be distributed to education and research. Allocation methods are necessary for this. A number of allocation methods have been discussed in this paragraph. For calculating the carbon footprint of the university, a combination of these methods may be used, depending on the usability of certain methods to certain emission sources. In the next paragraph, CO2 compensations, recycling and biogenic sources of carbon dioxide are discussed. These are topics that may add extra complexity to calculating carbon footprints. This literature can enable me to make a decision about whether to include or exclude these factors in my model, and how to incorporate these in my model if I decide to include them.

3.6 CO2 compensations, recycling and biogenic sources of carbon

3.6.1 CO2 compensations and carbon storage

Sometimes a company sets a certain goal about an emission reduction over a certain period. For example, a company might have a goal to reduce CO2 emissions by 30% by the year of 2015, compared to 1990. 1990 is then called a base year (WBCSD & WRI, 2003). However, goals related to carbon emissions may not always be reached. A question we could ask ourselves is: what should we do if we are unable to reduce our CO2 emission in the way we planned?

Carbon offsetting is a way to compensate for CO2 emissions. Organizations can invest in certain projects that are capable of reducing CO2 emissions for other organizations or to reduce CO2 in general. Planting trees is a commonly mentioned example for this. Trees are able to store CO2 (Strix hybridelease; Putt del Pino & Bhatia, 2002; Carbon Trust & Crown, 2008). Carbon offsetting can be used for companies that want their net CO2 emission to be zero. For example, if a company emits 200 tons of CO2 a year, then reduction projects that can reduce CO2 in the world with 200 tons a year could be done as "compensation" to get a net emission of zero (Putt del Pino & Bhatia, 2002).

The question is when organizations should be allowed to use carbon offsetting. If carbon offsetting is used in an organization's reports, then who is going to verify that the organizations actually reduced CO2 with a project? An important characteristic that an offset should have is that it is reached in a project that would not have been done without the organization's initiative. Organizations should demonstrate additionality (WBCSD & WRI, 2003). Furthermore, the GHG Protocol (WBCSD & WRI, 2003) states that offsets should be calculated by comparing actual emissions with a certain baseline scenario that indicates what emissions would have been without the project. Also, secondary effects of reduction projects should be quantified. This means that unintended consequences of a certain project, i.e. leakages, should also be incorporated into the analysis. The risk of reversibility should also be assessed, meaning that organizations should assess whether the CO2 reduction of a project is permanent.

When a carbon offset is compliant with certain rules, then it can be converted to a carbon credit. A carbon credit is an offset that can be exchanged on a market. For example, company A may have established an emission reduction of 200 tons CO2 this year. However, company A does not need this emission reduction to meet Kyoto Protocol targets. Therefore, company A goes to the Kyoto Protocol Clean Development Mechanism to get a Certified Emission Reduction (CER), which is a credit that can be sold on the market. This credit can enable other organizations to reach their Kyoto Protocol Targets (WBCSD & WRI, 2003). According to the GHG Protocol (WBCSD & WRI, 2003), the emissions of an organization should be reported separately and independently from their GHG trades.

The reason for planting trees is that trees store carbon. This is called "carbon storage". However, it is questionable whether planting trees has long-term benefits (Valkenburg, 2007; de Vries, 2008; van Peeterssen, 2011). Valkenburg (2007) considers planting trees to be a temporary solution only, because carbon stored in trees will get back in the environment over time. When trees get cut or get burned, then the stored CO2 will re-enter the environment. De Vries (2008) mentions that the most tangible effect of carbon offsetting is that people will feel peaceful in their mind, that they will feel less guilty. Van Peetersen (2011) states it is very hard to guarantee that permanent CO2-reductions take place. PAS 2050 excludes offsets in the life cycle assessment, because "PAS 2050 is an assessment of a specific product's life cycle GHG emissions; any reductions to the footprint should be directly attributable to changes made to the product's life cycle, not through unrelated activities such as purchase of emission credits" (Carbon Trust & Crown, 2008).

According to Milieu Centraal, CO2 compensation should take place by investing in sustainable sources of energy in development countries (De Vries, 2008). The United Nations allow projects in sustainable energy or energy efficiency for CO2 compensations, while planting trees is not allowed for CO2 compensation (Peeterssen, 2011).

This subparagraph has discussed the questionability of whether planting trees would reduce CO2 in the long term. However, there are other possibilities of using CO2 compensations as well. In the next chapter (chapter 4), an analysis is presented of whether to include CO2 compensation in CO2 calculations or not.

3.6.2 Recycling and remanufacturing

Organizations can use recycling to reduce CO2 emissions. By using recycling, certain products can be re-used. This gives the opportunity to reduce CO2 by avoiding CO2 emissions that would have occurred if the product had to be produced from scratch. The way in which emissions of recycled inputs are calculated depends on the recycling system. One recycling system that PAS 2050 talks about is a closed-loop system, which is a system where the recycled material is used as input for the same process, to create the same products again. When calculating emissions for these systems, the proportion of recycled materials in the input should be calculated. Using this information and the emissions of using recycled materials and virgin materials, a weighed estimate can be calculated of the average emissions of the process. When the system is not a closed-loop system, an assessment can be done based on BS EN ISO 14044 (Carbon Trust & Crown, 2008). At the disposal stage of a product that is going to be recycled, the emissions of this stage of the product should not be accounted for when calculating the carbon footprint (Carbon Trust & Crown, 2008).

Recycling can be distinguished from reusing and remanufacturing (CRR). Recycling means that the product is destroyed to be able to use its components again. However, for remanufacturing, the product itself can be reused again, after a remanufacturing process is done. PAS 2050 has a methodology for accounting of GHG emissions when remanufacturing is used. A product is used n times. The total manufacturing emissions are then computed, meaning that the emissions of the first manufacturing effort and the emissions of the n -1 remanufacturing efforts are added up. The total manufacturing emissions are then divided by the number of times the product is used, n, to get the average manufacturing emission for each time that the product is used. The use phase emissions can then be added up to this amount for the total emissions over one life cycle. In this paragraph several exceptions that could make calculations of carbon footprints harder have been discussed. In the next subparagraph, another of these exceptions is discussed.

3.6.3 Biogenic sources of carbon

One special emission category requires special attention in the calculation of GHG emissions: biogenic carbon. Biogenic carbon is “carbon in wood, paper, grass trimming, etc. that was originally removed from the atmosphere by photosynthesis and, under natural conditions, would eventually cycle back to the atmosphere as CO2 due to degradation processes” (CA-CP, 2010). Humans can cause emissions of biogenic CO2; these are called anthropogenic emissions of biogenic carbon. These emissions can include landfill gas, biodiesel, ethanol, or biomass combustion. Incinerator emissions are also mentioned by CA-CP. Mohna et al. (2008) and Johnke (2000) discuss fossil emissions and biogenic emissions in incineration. They both have done research about the proportion of biogenic CO2 in the total emissions.

This theory can be relevant when calculating carbon footprints. Emissions of fossil carbon increase the amount of CO2 in the atmosphere, because the carbon that was “locked away in fossil fuels is now available” (CA-CP, 2010). On the contrary, biogenic CO2 would have been returned to the atmosphere anyway, because of natural processes. Therefore, the Campus Carbon Calculator (CA-CP, 2010) and the corporate GHG protocol (WBCSD & WRI, 2003) suggest to report biogenic CO2 emissions separately. This means biogenic CO2 should not be included in scope 1, 2 or 3 (CA-CP, 2010; WBCSD & WRI, 2003). The reason for this is that anthropogenic biogenic CO_2 emissions do not increase the long-term amount of CO_2 in the atmosphere; it only increases the speed at which the CO_2 returns in the atmosphere (CA-CP, 2010).

According to CA-CP (2010), previous versions of their calculator even suggested that, “in keeping with IPCC guidance, biogenic emissions essentially be ignored or counted as ‘0’”. However, they also give the following recommendation: “if you are considering using any source of biogenic carbon, we recommend that you carefully evaluate whether your actions might lead to long-term changes in land-use, land-cover, or significant upstream emissions associated with fuel production”. If demand for biogenic carbon sources could, for example result in burning of trees to build a parking lot, then the emissions could be reported under scope 3. In addition, production of biogenic fuel sources may cause more emissions than production of conventional fuels. Therefore, for users of biofuels, it is common to check the significance of these emissions (CA-CP, 2010).

Emissions of N_2O or CH_4 emissions that have a biogenic source should be included in a calculation if the calculation also incorporates other greenhouse gases than CO_2 (CA-CP, 2010). This is a limitation of doing a CO_2-only calculation; significant emissions from other greenhouse gases (i.e. CH_4) that can cause harm to the environment are not accounted for in the calculation.

3.7 Verification

It can be useful to verify that the carbon footprint is calculated in the right way. This can be done in three ways according to PAS 2050 (Carbon Trust & Crown, 2008). First, independent verification could take place by a certification authority. They can decide whether the carbon footprint calculation process was conforming to a certain standard. The second possibility is verification by another third party that is not an accredited certification body. This may not provide stakeholders with the same amount of confidence as verification by an accredited third-party for certification. The third option is self-verification. This can be done by using the method described in BS EN ISO 14021. People may have less confidence in this option.

The GHG Protocol (WBCSD & WRI, 2003) also contains a section about verification. According to the GHG Protocol, verification involves “an assessment of the risk of material discrepancies in reported data. Discrepancies relate to differences between reported data and data generated from the proper application of the relevant standards and methodologies”. The GHG Protocol states that the main goal of verification is giving confidence to stakeholders about the correctness of the GHG emissions that are reported by an organization. Transparent data of the organization can make it easier to verify the data.

Just like with PAS 2050, the GHG Protocol (WBCSD & WRI, 2003) discusses several methods of verification. Internal and external verification is possible. Using third party data can increase the credibility of the calculated footprint. Organizations have to assess the risk of material discrepancy for each part of the process of calculating the carbon footprint. A material discrepancy is a significant deviation from the actual value of certain data. When the risk of material discrepancy for each part is assessed, then this can aid organizations in knowing where to focus on for verification. The organization can verify the whole GHG inventory, or only parts of it. The organization should clearly communicate the scope of work of the verification to their stakeholders to ensure transparency and credibility (WBCSD & WRI, 2003).

There are more choices that an organization should make for its verification process according to the GHG protocol. Decisions need to be taken about possible sites that the verifiers will visit. Furthermore, timing of the verification has to be decided. The verifier also has to be selected based on a number of selection criteria. When these choices are made, companies have to prepare for their GHG verification. Organizations have to ensure that the necessary data for verification is available. Organizations have to establish an audit trail of how the carbon footprint was calculated. The verifier has to be able to see what steps were taken and what data was used to calculate the carbon footprint (WBCSD & WRI, 2003).

In this paragraph, certain methodologies of assessing the correctness of the carbon footprint data are discussed. Organizations can take multiple steps if they want to be more certain about the correctness of their calculations. There are multiple ways to ensure verification: certification, non-accredited third party validation and self-verification. Organizations have to make a choice on which verification to use.

3.8 University-specific literature

So far, general literature about calculating footprints of organizations or office-based organizations in particular has been discussed. Since this research is specifically about the calculation of the carbon footprint for universities, in this paragraph, some literature about calculating carbon footprints of universities is discussed. Just like with the general literature discussed before, an emission for a university can be calculated by multiplying the activity data with an appropriate emission factor. However, there are some differences between emissions of universities and emissions of other companies. For example, a company that produces beer typically has different emission sources than universities. The literature that is discussed in this paragraph mainly deals with emission sources of universities and collecting the required data for calculating the carbon footprint.

3.8.1 Relation between university-specific literature and general methodologies

Three main sources have been consulted when it comes to university-specific literature (ACUPCC, 2009; CA-CP, 2010; Dautremont-Smith, 2002). The implementation guide of the American College & University Presidents' Climate Commitment (ACUPCC, 2009) discusses GHG inventories for universities. Presidents who became the founding signatories of ACUPCC agreed to some common points. In the implementation guide, several obligations of the signatories are described, as well as certain recommendations.

The ACUPCC initiative allows the participating organizations to use any quantification methodology that is according to the GHG Protocol (WBCSD & WRI, 2003). ACUPCC (2009) recommends universities to use the Campus Carbon Footprint calculator, as it is "the most user-friendly and appropriate tool currently available for application in the higher education context". Clean Air-Cool Planet has created the Campus Carbon Footprint calculator (CA-CP, 2010). For creating this method, standards like IPCC and the corporate GHG Protocol (WBCSD & WRI, 2003) have been used. Dautremont-Smith (2002) has used some guidelines from IPCC to create his guidelines for college-level GHG emissions inventories.

3.8.2 Time period

According to ACUPCC (2009), universities can choose to report GHG emissions for a calendar year, academic year or fiscal year. CA-CP (2010) mention that universities can choose to report emissions for a calendar year or a fiscal year, not mentioning academic years. According to them, universities are mostly using fiscal years.

3.8.3 Organizational boundaries

CA-CP (2010) discusses organizational boundaries in their users guide to the Campus Carbon Calculator. Organizational boundaries have to be chosen by the organization to decide where carbon emissions should be reported and measured. For example, emissions could be measured for one department, or for the whole campus. They refer to the GHG Protocol (WBCSD & WRI, 2003) with regards to the two ways of setting organizational boundaries: equity share and control. These two methods have been described in the allocation paragraph of this chapter. CA-CP states that universities have to choose and consistently apply one of these two approaches. The university has to decide which approach suits them best. An example of such a choice that has to be made: a university could sometimes own a number of buildings, while not being in control of all of these buildings. This could i.e. be the case when the university owns student housing. The decision to choose the control or equity approach can then be the difference between including and excluding student housing in their scope 1 emissions. When operational control is used, then emissions of the student housing will be excluded in the scope 1 emissions.

These emissions can then be included in scope 3. The GHG Protocol (WBCSD & WRI, 2003) states that organizations have to decide which emission categories they want to include for scope 3. If the organizational boundary does not allow a certain emission category to be reported under scope 1, then the organization could choose to report it under scope 3. CA-CP (2010) states that the institutional boundary tells us if the emission category (in this example emissions of student housing) should be reported under scope 3 instead, or if it is not reported at all. Institutional boundaries are discussed in subparagraph 3.8.5.

3.8.4 Emission sources of universities

Each of the three main sources of literature used for this chapter discuss certain types of emissions that can be included in the analysis for universities. ACUPCC (2009) refer to the GHG Protocol (WBCSD & WRI, 2003) for explaining the different types of emission categories. For scope 3, ACUPCC state that their signatories have to report some scope 3 emissions: air travel that is financed by the university and commuting. Commuting is defined as “travel to and from campus on a day to day basis by students, faculty, and staff”. The guidelines by ACUPCC also recommend reporting additional emissions, especially “those from sources that are large and can be meaningfully influenced by the institution”. However, some emissions that are hard to measure and that are not a big part of the total emissions may be excluded from the GHG inventory, as long as the emissions that are excluded are in total less than 5% of the total GHG emissions (ACUPCC, 2009).

CA-CP (2010) has a very detailed calculation method for calculating GHG emissions. They provide extensive Excel sheets to calculate the GHG emissions of a university. Not only CO2 emissions are tracked in the model, also other GHG emissions. Many categories of emissions are present in the model. For scope 1, the emissions that are described in the user guide are very similar to the emissions that are described by the GHG Protocol (WRI & WBCSD, 2003). However, physical and chemical processing is excluded. Scope 1 emissions are divided into different categories:

- On campus stationary source(s), which can use fossil fuels, incinerated waste, wood, bioheat, etcetera.
- University fleet: emissions from the different types of fuel that can be used in the university's fleet (including gasoline, diesel, hydrogen, etcetera)
- Emissions from refrigerants and chemicals
- Agriculture (only NO_2 and CH_4 emissions, CO_2 is excluded for this category)

Scope 2 emissions that are described are almost identical to the ones described in the GHG Protocol. Scope 2 consists of emissions of purchased electricity, steam and chilled water. For purchased electricity, kWh is the main input. Organizations have the choice to enter their electricity mix as well, if they desire a more detailed calculation. For steam and chilled water, the university can choose to enter their fuel mix and their boiler efficiency.

For scope 3, emission categories are bit more specific to universities. Scope 3 emissions of universities can include (CA-CP, 2010):

- Managing the institution's waste, i.e. incineration and landfilling. Landfilling is not included in the CO_2 calculations, but only for CH_4, N_2O and CO_2e.
- Wastewater (also not included in the CO_2 calculations)
- Directly financed outsourced transportation (i.e. employees travelling in vehicles not owned by the institution where mileage is reimbursed, business travel in commercial aircrafts, etcetera.)
- Emissions from regular commuting by faculty, staff or students, by automobile, bus, light rail or commuter rail.
- Study abroad air travel
- Transportation and distribution losses from purchased energy
- The amount of paper consumed and its recycling percentage (0 / 25 / 50 / 75 / 100 % recycled).
- "Upstream emissions from directly financed purchases". Paper production, food production and fuel extraction are included in this category. However, only paper is present in the calculation sheet.

Offsets are also included in the calculation sheet of CA-CP (2010). The "net emissions" can be calculated by subtracting the amount of offset emissions from the total emissions (in terms of CO_2 equivalents, CO_2e) that are computed by adding up the emissions of the three different scopes of the company. The CA-CP tool also computes CO_2 emissions separately. However, for paper (scope 3), only CO_2 equivalents are calculated, and no CO_2 emissions in particular, even though the production and transportation of paper definitely has CO_2 emissions. In addition, only negative CO_2 emissions are reported for waste, even though waste processing sometimes has a positive CO_2 emission (depending on the type of waste and the way of processing).

Dautremont-Smith (2002) created a guide for universities and colleges on how to do a GHG emissions inventory. It is the result of a summer research project and a year of refining the method. According to Dautremont-Smith (2002), the four most significant sources of GHG emissions of a random college or university are probably "electricity consumption, on-campus combustion of fossil fuels for heat and cooling, commuters coming to campus, and air travel paid for by the college". Dautremont-Smith divides emissions into a number of main categories:

- GHG emissions from energy
- GHG emissions from transportation
- GHG emissions from solid waste
- GHG emissions from wastewater (for NO2 and CH4, not interesting for this study)
- GHG emissions from other emissions sources

For energy, natural gas, electricity, distillate fuel, residual fuel, propane and liquefied petroleum gas (LPG) are included. For electricity, it is recommended to gather data about the exact fuel mix that is used by the university, to be able to calculate electricity emissions in a more exact way (Dautremont-Smith, 2002). According to Dautremont-Smith, there is some debate on how to incorporate nuclear power and hydro power. The VRGGP suggests zero CO2 emissions, while Rob Edwards points out that fossil fuels are burnt in the production of nuclear power, which of course emits CO2. In addition, extracting and transporting the uranium also create emissions. Dautremont-Smith (2002) decided only to account for emissions of the combustion, and not to account for emissions of extraction and transportation of fuels. For this reason, the emissions coefficient of solar and wind energy also is zero in Dautremont-Smith's guidance, even though production of solar panels and wind turbines cause GHG emissions. However, later in his text, Dautremont-Smith mention that universities and colleges have to make sure that possible green power that they use is actually produced without GHG emissions.

When calculating electricity consumption, line loss (electricity lost in transportation) should be incorporated in the calculation. The percentage of line loss is dependant on a university's distance to the production facilities. However, Dautremont-Smith (2002) states 10.5% would be a reasonable default value for the line loss.

A number of different emission categories for transportation can be distinguished according to Dautremont-Smith (2002): college gasoline consumption; college mileage and gasoline purchase reimbursements; student, faculty and staff commuting to campus; air travel by college staff, faculty, athletic programs and overseas programs. Automobile travel, bus travel and air travel are included in the guidance for these categories.

For emissions from solid waste, Dautremont-Smith excludes decomposition of solid waste for CO2. However CO2 emissions due to combustion of solid waste (or municipal solid waste, MSW) are included. The presence of biogenic and non-biogenic emissions can make the calculations more complex. Subparagraph 3.6.3 provides more information about this topic. When it comes to the last category, "GHG emissions from other emission sources", the only sources of CO2 are limestone and dolomite application in this category in the guide of Dautremont-Smith (2002).

Aside from factors that raise the carbon footprint, there can also be factors that reduce the carbon footprint. An example of this is electricity generation from waste. If waste is combusted in a facility that produces electricity, then this amount may be deducted from the total electricity consumption according to Dautremont-Smith (2002). Universities can also use composting, which is a much better alternative than incineration when the total environmental impact would be regarded rather than a single focus on CO2.

Dautremont-Smith (2002) states that a number of emission sources are currently not possible to include in GHG inventories: land use, lifecycle emissions, recycling, construction/ subcontracting, refrigerants and landfill sequestration. He gives multiple reasons for this. For land use, he believes there are no suitable standards available. He calls calculations for lifecycle emissions "complex" and "a relatively new science". Because lifecycle emissions are not included, recycling is also not included in his calculation. Construction is not included, because fuels used for the equipment are not paid for by the university, which makes it hard to evaluate these emissions. Similarly, the method of Dautremont-Smith (2002) does not account for emissions from outsourced services, which could be the bookstore or the restaurant. Refrigerants were excluded, because Dautremont-Smith (2002) could not find any data on average leaking amounts of refrigerators. Furthermore, he believes refrigerators do not have a large contribution in the total GHG emissions of the organization. Finally, landfill sequestration is excluded, because most products that could be landfilled are purchased, and Dautremont-Smith (2002) does not include lifecycle emissions.

Earlier in this subparagraph, I discussed ACUPCC's statement saying that some small emissions may be excluded, as long as the sum of these emissions is less than 5% of the total GHG emissions (ACUPCC, 2009). PAS 2050 allows emissions that are less than 1% of the total emissions of the product or service to be excluded from the analysis, as long as the total percentage of emissions that is excluded does not exceed 5% (Carbon Trust & Crown, 2008). On the contrary, the GHG Protocol (WRI & WBCSD, 2003) states that such a materiality principle is not consistent with the completeness principle of the standard. CA-CP (2010) recommends including small emission sources (that add up to less than 5% of total emissions) in the GHG inventory for universities. Upper-bound estimates can be used for a longer period to include these types of emissions in the assessment, while making it possible that not too much time is spent in gathering the data. As examples of such de minimus emissions, CA-CP (2010) talks about "wastewater, student commuting, methane and nitrous oxide from biogenic sources, propane, off-road diesel, emissions from buildings that are marginal to campus operations or have outdated energy monitoring systems".

For creating my model, I had to know first which emissions to include in my model. In paragraph 3.3, many emission sources are already discussed. Examining the literature as discussed in this subparagraph has given me a better idea about which emissions I could possibly include in my model, by focusing on specific emission categories for universities. The next subparagraph focuses on boundaries that universities could choose on what emissions to include.

3.8.5 Institutional boundaries

The guide to the Campus Carbon Calculator (CA-CP, 2010) talks about decisions that institutions have to make on what categories of emissions to include in the inventory. The boundaries that are the result of such decisions are called institutional boundaries. CA-CP recommends that universities use one of the following institutional boundaries:

- All scope 1 and scope 2
- All directly financed emissions
- All directly financed emissions, plus selected directly encouraged emissions

- All directly financed or significantly encouraged emissions, plus selected upstream emissions.

Reporting all scope 1 and 2 emissions is required to be compliant with the corporate GHG protocol (WRI & WBCSD, 2003). According to CA-CP (2010), this "is the bare minimum for most inventories". All directly financed emissions means reporting all scope 1 and 2 emissions, plus scope 3 emissions that are directly financed by the institution. Although scope 3 emissions are not direct emissions of a company, financing certain activities that lead to emissions (e.g. air travel) can give a certain responsibility. Reporting these emissions as well could provide more incentives for the organization to try to reduce these emissions.

Directly encouraged emissions may also be included in the assessment (CA-CP, 2010). Directly encouraged emissions are emissions that occur, because the institution "encourages" people to make use of certain sources that emit greenhouse gases. An example of such an emission is the emission resulting from commuting when the university does not pay for the travel of an employee. In this case, commuting can be considered necessary for the employee to be able to work, so it can be included in the GHG inventory.

In addition, certain upstream emissions may be included in the analysis. According to CA-CP (2010), emissions from producing and transporting paper are examples of such emissions. Organizations might want to report a decrease in emissions, when they are planning an initiative to reduce the amount of paper consumption in the organization. To be able to report this, measuring emissions of paper consumption would be useful to prove their emission reductions.

3.8.6 Data collection

Many types of data are required for the calculations of the Campus Carbon Calculator. In this subparagraph, an overview is provided of ways to get certain data. When collecting activity data, data is likely to come from many different sources within the university. According to CA-CP (2010), the Physical Plant, Facilities Office, Campus Planning Office and local Utilities are good places to start with gathering the data. Different universities usually have different ways of storing carbon related data.

Firstly, CA-CP (2010) recommends gathering institutional data. The number of faculty and staff should be known, as well as the number of part-time and full-time students. To gather this data, the Institutional Research and Assessment could be contacted, or maybe the Registrar or Human Resources. Another type of institutional data that is necessary according to CA-CP (2010) is "physical size". Building space in square feet should be gathered for the building(s). Aside from institutional data, activity data that relate to scope 1, 2 or 3 emissions have to be gathered.

Scope 1: campus' stationary sources.
The energy manager, director of facilities or fuels purchaser can be contacted for gathering data on the types and amounts of fuels used on campus. If such information has not been compiled yet, then digging through energy bills may be necessary. For direct transportation sources, the director of transportation can be contacted to find out who is in charge of managing fleet fuel use. When it comes to refrigerants and other chemicals, the director of facilities, plant maintenance or air conditioning managers can be contacted (CA-CP, 2010).

Scope 2: purchased electricity, steam and chilled water.
For electricity, it is possible to contact the energy manager or the director of facilities. Data on electricity may be found in monthly records at the Energy Office. For electricity, the kWh and the fuel mix should be known. For purchased steam and chilled water, the same people may be contacted as for electricity, or the steam or chilled water provider may be contacted for knowing the fuel mix that is used to produce the steam or chilled water. Aside from the amount of energy consumed, the fuel mix and transmission loss should be known (CA-CP, 2010).

Scope 3: commuting of faculty, staff and students.
Commuting can be a tough category to measure. Details about residence of students (to be able to calculate distance) can likely be found at the Registrar, while the same data for employees can often be found at Human Resources. The Transportation Office may be contacted for information on the travelling habits of commuters.

Scope 3: Directly financed outsourced travel.
Data about the number of miles travelled may be able to be retrieved from the university's travel office, or from a travel agent. Study abroad air travel is also part of the emissions that may be reported under scope 3. Data about distance travelled may be found at the study abroad office of the registrar's office.

Scope 3: Solid waste .
First, data has to be collected about the amount of waste. Waste management could be contacted for this. Second, information on how the waste is disposed is required (CA-CP, 2010). The Campus Carbon Calculator (CA-CP, 2010) uses emission factors for an "average" composition of solid waste. However, an emission factor for a specific composition of waste may be calculated as well. This could be done by using a tool from EPA (2011).

In this subparagraph, it became clear that there are many possibilities when it comes down to the places where data is stored in universities. Different universities may report the same categories of information in different places in a different way. When a university is calculating its GHG footprint, information is likely to come from many different sources in the university. People who have to gather this data must realise that it may take a while before all the necessary data is gathered.

4 Analysis

4.1 Chapter Introduction

This chapter consists of four paragraphs. In the literature review, three important calculation methodologies for the carbon footprint were described. In paragraph 4.2, the relevance of three calculation methodologies, PAS 2050, the GHG Protocol and the Campus Carbon Calculator will be examined to decide what calculation methodologies are useful for the calculation of CO2 emissions of universities. In paragraph 4.3, reports of universities will be examined to see what CO2 emission categories are the most significant for universities. In paragraphs 4.4 and 4.5, a basic description of my model is given. The most relevant calculation methodology that I find will be taken as the basis for my model. The reports of universities will be taken as input in the decisions that I make on the content of my model, because these reports enable me to see what the most significant CO2 emission categories are for universities. In chapter 5, the case study, my model will be described in more detail, because the method of calculation is partly dependant on the extent to which the necessary activity data is available in an organisation.

4.2 Reflection on calculation methodologies

The most important literature on carbon footprinting discussed during the literature review is: PAS 2050 (BSI, 2008; Carbon Trust & Crown, 2008), the Corporate Greenhouse Gas Protocol (WRI & WBCSD, 2003) and the Campus Carbon Calculator (CA-CP, 2010). PAS 2050 and the corporate GHG protocol are widely recognized standards, and the Campus Carbon Calculator is probably the most widely used calculation method for universities. The goal of this paragraph is to analyze the extent to which these pieces of literature would be sufficient for calculating the amount of CO2 emitted by a university.

4.2.1 PAS 2050

PAS 2050 (BSI, 2008) is a standard for calculating the carbon footprint of products or services over the life cycle. It enables an organization to calculate the carbon footprint of a product or service in great detail. There is a detailed guide available for using the model (Carbon Trust & Crown, 2008). Many exceptions, like carbon storage, are discussed.

However, PAS 2050 is not a model that fits what we are trying to achieve: quantifying CO2 emissions from universities. PAS 2050 is a model that is focused on the life cycle of a single product or service. Therefore, PAS 2050 is a model that is more suitable for companies that produce a certain product, to quantify emissions of that product. Furthermore, PAS 2050 is not a standard that is specifically designed for CO2; it is a standard for greenhouse gases in general.

4.2.2 The GHG Protocol

The corporate GHG protocol (WRI & WBCSD, 2003) is a standard that comes more close to what I am trying to achieve. The GHG protocol is developed to report on GHG emissions of an entire organization. I want to calculate CO2 emissions for an entire university, which makes a standard for entire organizations quite helpful. The GHG protocol enables an organization to use data from multiple sources to make a GHG inventory of the entire organization. The GHG protocol provides a very elaborate description of what could cause CO2 emissions of an organization. The separation in scopes is a very good feature in the model. Using these scopes, it can become clear whether an organization emitted the CO2 themselves, or whether they bought a certain product, which created CO2 emissions during its manufacturing.

However, there are downsides to this model as well, at least for my purpose. The GHG protocol is not a standard which is specifically designed for universities. This means that using the GHG protocol would mean that I would have to define emission categories for universities specifically, but that would still comply with the GHG protocol. Furthermore, the GHG protocol measures GHG emissions in general, rather than only CO2 emissions. The consequence of this is that certain emission categories are not useful when calculating the amount of CO2 emitted by a university. Another downside of the model is that it does not provide one single calculation tool for a certain sector. For calculating emissions of office-based organizations, multiple calculation tools of the GHG protocol would have to be used together, but even then still additional manual calculations would be necessary.

The corporate GHG standard (WRI & WBCSD, 2003) provides some useful explanations about allocations, but does not focus on allocation within a company. I am interested in allocating emissions to both education and research within the university. WRI and WBCSD are currently developing a method of accounting for corporate GHG emissions of scope 3 (WBCSD & WRI, 2010). In their provisional document, much useful information is given about possible ways of allocation within an organization. This could be very useful for finding methods to allocate emissions to research and education in the university.

4.2.3 Campus Carbon Calculator

The Campus Carbon Calculator (CA-CP, 2010) is designed by Clean Air-Cool Planet, an American organization that is dedicated to finding and promoting solutions to global warming. The Campus Carbon Calculator makes use of the GHG protocol, i.e. by categorising emissions into different scopes. This is a positive feature, because the GHG protocol is a widely used standard. The Campus Carbon Calculator is a calculator that is specifically designed for calculating GHG emissions of universities. This means that the emission categories consist of emissions that are often found in universities. Just like the GHG Protocol, many different types of emissions can be found in the Campus Carbon Calculator. Therefore, this model is very much applicable to this research. A guide is provided with the calculator, which amongst others gives an explanation about data collection.

In my opinion, this tool is very useful for calculating the amount of GHG emissions for a university. But there are also some downsides to this model, especially when it comes to CO2 -specific calculations and allocation:

- The model is not specifically designed for CO2 emissions. Some emission categories that are included in the model are not relevant for my purpose, because there are categories of emissions for other types of emissions than CO2.

- The model does not allow for allocation within the university. The emissions of the university are calculated, while not offering an approach to distribute emissions between education and research.
- CO_2 emissions are not reported specifically for paper. In addition, emissions of water are not included.
- It is not possible to enter the entire waste mix in the calculation sheet. Instead an emission factor is used for determining the average waste composition.
- The Campus Carbon Calculator only offers four ways of travelling for commuting (automobile, bus, light rail, commuter rail), whereas commuting is probably the biggest source of CO_2 emissions for universities. Emission categories like ferry, scooter, moped motorbike, metro and tram are missing for commuting. Furthermore, in the category "automobile" the Campus Carbon Calculator does not make a distinction between different types of fuels like gasoline, diesel, etcetera.
- Documentation about the actual calculations is limited; the method could have been made more transparent, in order to be better able to understand the calculations in the model .

To conclude, the corporate GHG Protocol (WRI & WBCSD, 2003) and the Campus Carbon Calculator (CA-CP. 2010) can be very useful tools for calculating GHG emissions of a university, although they can still be improved. This paragraph clarified the good sides and the downsides of the discussed literature. Both sides were taken into account when developing my own model, which is presented further in this document. For my model, the Campus Carbon Calculator (CA-CP, 2010) was used as the basis.

4.3 University reports

The literature discussed before has already given me a good idea of which emission sources can be important for companies. In addition, I have examined some reports of universities that calculated their CO_2 footprint, in order to further help me in verifying what the important emissions of universities are, and to give a better idea of possible outputs that the various tools could give. I discuss three reports that measured CO_2 output specifically. Two of these reports measured their CO_2 emissions by using the Campus Carbon Calculator; the other one used a tool called the "Milieubarometer".

The first examined report is the report of the University of Toronto (2009). They measured their CO_2 emissions by making use of the Campus Carbon Calculator. Results of the measurement can be seen in the following table:

Emission Source	Greenhouse Gases						
	CO_2 (kg)	CH_4 (kg)	N_2O (kg)	HFC (kg)	PFC (kg)	SF_6 (kg)	CO_2e (mt)
Co-gen Electricity	13,315,510	1,331	27	-	-	-	13,354
Co-gen Steam	13,314,955	1,331	27	-	-	-	13,353
Other on-campus stationary	56,355,720	5,700	122	-	-	-	56,523
Direct transportation	231,560	44	15	-	-	-	237
Refrigerants & chemicals	-	-	-	515	-	-	764
Fertilizer application	-	-	51	-	-	-	15
Scope 1 – Total	83,217,745	8,407	242	515	-	-	84,247
Purchased electricity	48,731,344	602	739	-	-	-	48,964
Purchased steam	5,085,473	508	10	-	-	-	5,100
Purchased chilled water	150,440	2	2				151
Scope 2 – Total	53,967,256	1,113	751	-	-	-	54,215
Faculty / Staff commuting	8,301,167	1,419	500	-	-	-	7,549
Student commuting	18,541,346	2,145	813	-	-	-	15,065
Financed air travel	1,255,711	12	14	-	-	-	1,260
Other financed travel	110,758	22	8	-	-	-	114
Waste Disposal	-	-	-	-	-	-	2,041
Scope 3 – Total	23,587,584	3,014	1,117	-	-	-	26,029
All scopes	**160,772,585**	**12,533**	**2,110**	**515**	**-**	**-**	**164,491**

Figure 5: Greenhouse Gas Emissions of the University of Toronto (1 May 2008 - 31 April 2009)

This university cogenerated some electricity and steam themselves, resulting in significant emissions. Other on-campus stationary sources are the biggest source of emissions when looking at the total. Purchased electricity and steam also relatively produces much CO2. Faculty, staff and student commuting are also significant CO2 emitters. Surprisingly, air travel is not a big part of the university's emissions. No CO2 emissions are accounted to waste disposal or refrigerants and chemicals. Total emissions are the highest in the scope 1 category and the lowest in the scope 3 category. 160,8 million kg of CO2 is emitted, while 164,5 million kg CO2e is emitted. This shows that reporting CO2 emissions only could have given a reliable estimation of the total CO2 emission of this university. However, it has to be noted that, if only CO2 was included in UoT's calculation, no emissions of refrigerants & chemicals or waste disposal would have been reported.

The next educational institution examined is Lakeland Community College (2009). They seem to have used a more recent version of the Campus Carbon Calculator than the University of Toronto. Below the summary of their GHG emissions is available:

MODULE	Summary					
WORKSHEET	Overview of Annual Emissions					
UNIVERSITY	Lakeland Community College					
Select Year -->	2009	Energy Consumption	CO_2	CH_4	N_2O	eCO_2
		MMBtu	kg	kg	kg	Metric Tonnes
Scope 1	Co-gen Electricity	-	-	-	-	-
	Co-gen Steam	-	-	-	-	-
	Other On-Campus Stationary	44,830.1	2,365,046.8	236.5	4.7	2,371.9
	Direct Transportation	1,490.7	104,825.3	19.6	6.8	107.3
	Refrigerants & Chemicals	-	-	-	-	6.7
	Agriculture	-	-	-	31.3	9.3
Scope 2	Purchased Electricity	80,240.5	7,310,881.4	61.8	136.9	7,352.8
	Purchased Steam / Chilled Water	-	-	-	-	-
Scope 3	Faculty / Staff Commuting	17,851.4	1,251,749.2	250.4	86.2	1,283.0
	Student Commuting	208,270.4	14,608,903.6	2,899.7	999.1	14,971.3
	Directly Financed Air Travel	236.2	46,381.7	0.5	0.5	46.5
	Other Directly Financed Travel	448.9	31,569.8	5.9	2.0	32.3
	Study Abroad Air Travel	-	-	-	-	-
	Solid Waste	-	-	5,830.0	-	134.1
	Wastewater	-	-	1,633.8	11.5	41.0
	Paper	-	-	-	-	255.5
	Scope 2 T&D Losses	7,935.9	723,054.2	6.1	13.5	727.2
Offsets	Additional					-
	Non-Additional					-
Totals	Scope 1	46,320.9	2,469,872.1	256.1	42.8	2,495.2
	Scope 2	80,240.5	7,310,881.4	61.8	136.9	7,352.8
	Scope 3	234,742.8	16,661,658.4	10,626.4	1,112.9	17,491.0
	All Scopes	361,304.1	26,442,412.0	10,944.3	1,292.6	27,338.9
	All Offsets					-
					Net Emissions:	27,338.9

Figure 6: Annual Emissions of Lakeland Community College

CO2 emissions for scope 3 are the biggest source of emissions for Lakeland Community College, while emissions of scope 1 are the lowest. This is exactly the opposite of the University of Toronto. Another surprising factor is the amount of student commuting emissions, when comparing it to other emissions. Student emissions amount to more than 50% of the total CO2 output, according to these calculations. On-campus stationary sources and electricity are other big sources of emissions. Lakeland emitted 26,4 million kg CO2, while emitting 27,3 kg CO2e. Again, there is only a small difference between the weight of the total CO2 emission when compared to the total CO2e emission. However, paper and solid waste are categories that wouldn't have been reported if only CO2 would have been included in this report.

The last report examined is the report by the EUR, done by Thomas Healsig, the student Assistant of Greening the Campus at the time (2009). Here CO2 emissions are measured by using the "Milieubarometer". The Milieubarometer is an online measurement instrument that can make the environmental score, carbon footprint and accompanying costs visible for an organization. It was initially created in 1999 by Stichting Stimular and CE Delft. In 2010, an update was done to the Milieubarometer. The CO2 footprint is measured in CO2 equivalents in the Milieubarometer. The Milieubarometer has advantages and disadvantages. Many organizations use the Milieubarometer, which makes comparisons possible between organisations. Furthermore, the tool is cheap, easy to use and provides a nice overview of emissions. There are also some disadvantages. First, the tool does not contain a lot of emission categories for CO2, like waste, water, paper and direct transportation. Second, the tool is not clear about the fact that they use CO2 equivalents. Third, the Milieubarometer is not used by other universities, which makes it hard to compare the EUR's CO2 emissions with other universities if the Milieubarometer would be used. Below, the results of the CO2 calculation of the EUR in 2007 can be found. CO2 emissions are displayed in tons CO2e (which is unclear in the table below). Furthermore, the percentages are percentages of the total environmental impact and not percentages of the total CO2 emission:

EUR 2007		%	Tons CO_2
	Paper	0,6	
	Work-related Travel	10,6	2578
	Home-Work Travel	55,6	7807
	Waste	4,3	
	Waste & Wastewater	0,4	
	Fuels	0,8	219
	Electricity	27,7	6762
	Total	100	17366

RSM 2007		%	Tons CO_2
	Paper	0,6	
	Work-related Travel	18,6	1156
	Home-Work Travel	66,8	2380
	Waste	5,6	
	Waste & Wastewater		
	Fuels	0,2	14
	Electricity	8,2	510
	Total	100	4059

Table 1: Results Milieubarometer EUR 2007

CO2 emissions of both the entire university (EUR) and the Rotterdam School of Management (RSM), which is the biggest faculty of the EUR, were measured. Not many different categories were used. However, something notable is that fuel only seemed to be contributing to a small amount of emissions.

In this paragraph, some examples were given of CO2 reports of companies, which has given a better understanding of what can be important emission sources for CO2 in relation to educational institutions. In the next paragraph, I explain which emission categories I believe are relevant for measuring CO2 emissions of universities.

4.4 Emission categories in the model

This paragraph explains which emission categories are included in my model and why these categories are included. The Campus Carbon Calculator (CA-CP, 2010) is the basis for deciding which emission categories to include in my model. The Campus Carbon Calculator divides its emissions into three scopes. For each scope, I examined each emission category that is present in the Campus Carbon Calculator and decided if it should be included in my model. There is one other statement that I would like to make. For all emission categories, only the part that is relevant to Erasmus University Rotterdam is included in the model. For example, if EUR does not own cars that use LPG as a fuel, then LPG is not included in the calculation, even if it is included in the Campus Carbon Calculator. Although my model is not as elaborate as the Campus Carbon Calculator, it is very transparent and includes more emission categories for CO2 than the Campus Calculator. Other universities that are interested in calculating CO2 emission instead of CO2 equivalent emissions could use my model as a basis and expand it to incorporate emission categories or subcategories (like LPG) that would be relevant for them.

4.4.1 Scope 1

A number of emission categories present in the Campus Carbon Calculator are not included in my model. First, refrigerants and chemicals are not part of the calculation, because I could not find carbon dioxide-specific emission factors for this. The Campus Carbon Calculator did not calculate CO2 emissions of refrigerants and chemicals. Instead, it calculated the emissions of refrigerants and chemicals only in CO2 equivalents. It is therefore questionable whether the CO2 emission of refrigerants and chemicals is significant. In addition, there are no CO2 emissions of agriculture in the Campus Carbon Calculator. Therefore, I do not include agriculture in my calculation.

Some categories are relevant for CO2 calculations, but are not relevant to the Erasmus University Rotterdam. These categories should be included into calculations of CO2 for universities that have significant emissions in these categories. Categories that are not relevant to the EUR are categories that are part of on-campus cogeneration plants. The EUR does not produce electricity or heat themselves; therefore this should not be included in my CO2 calculation.

There are only two scope 1 categories left for EUR:

- Direct transportation; in this case the emissions of the owned vehicles of the EUR. However, the EUR only owns a diesel and a gasoline vehicle; therefore, other fuels are not included in my model.
- On-campus stationary sources other than “on-campus cogeneration plants”. An example of an “other on-campus stationary source” is a furnace.

It should be noted that, although I allocate all the emissions of direct transportation and on-campus stationary sources to scope 1, this is not entirely correct. The reason for this is that the emission factors that I have used for both direct transportation (diesel and gasoline) and on-campus stationary sources (natural gas) are life cycle emission factors. These emission factors cover the emissions over the life-cycle of a fuel, from extraction to combustion.

Actually, emissions that are not directly the cause of activities of the university (like production of fuels), should be reported under scope 2 or 3. There are a few reasons why I chose to report the whole life-cycle direct transportation and on-campus stationary under scope 1 in the case of Erasmus University Rotterdam:

- Total emissions of direct transportation and on-campus stationary sources of the EUR represent only a small portion of the total emissions of the EUR. Therefore I believe creating a new scope 2 or 3 emission category that includes production and transportation of these fuels would be a bit too much.

- Most emissions related to direct transportation and on-campus stationary sources are part of scope 1 emissions.
- The Campus Carbon Calculator (CA-CP, 2010) also chose not to report emissions of production or transportation of fuels that are used for combustion in university-controlled vehicles or other emission sources in scope 2 or 3.

I recommend that, if a university wants to include entire life-cycle emissions of fuels in their assessment, that they do report emissions of fuels for direct transportation and on-campus stationary sources that are not related to combustion under scope 2 or 3 if the emissions of these categories are a significant part of the university's emissions. This could be the case if a company produces heat and/or electricity themselves, or when the university would own a lot of vehicles themselves. In these cases, emissions of processes like extraction and transportation of fuels are probably significant.

4.4.2 Scope 2

Two categories are present in my model that fall under scope 2: purchased electricity and purchased heat. For purchased electricity, different sources of electricity are present in the model, as the Erasmus University Rotterdam uses (green) electricity coming from a number of sources: water power, wind power and bio mass. Purchased heat is one category, instead of the separation into purchased steam and purchased chilled water that the Campus Carbon Calculator uses. The reason for this is that the EUR only buys heat, instead of steam and chilled water.

4.4.3 Scope 3

Within the Campus Carbon Calculator, scope 3 is the scope with the highest number of categories. The only categories that are not used are wastewater and "landfilled waste", because these do not emit CO2 but only CO2 equivalents.

Some categories in the Campus Carbon Calculator contain less sub categories in my model, others contain more subcategories in my model. For directly financed outsourced travel, only air and train are included in my model, as data about other travels has not been found for Erasmus University Rotterdam, and I believe other transportation methods are not as much used for outsourced travel. Paper does not contain any subcategories, but the presence of a CO2 calculation for paper is already an improvement to the Campus Carbon Calculator, where only CO2 equivalents were calculated for paper. The reason for not including more categories for paper was that reliable emission factors were hard to find for paper, and data that could help me categorize the different paper types that the EUR uses could not be found.

When it comes to faculty and student commuting, many more subcategories are included in my model in comparison to the Campus Carbon Calculator. For two of the three reports that were examined in paragraph 4.3, CO2 emissions of commuting were more than 60% of the total CO2 emissions. Therefore, a more elaborate categorisation of CO2 emissions of commuting was necessary. Instead of only providing automobile, bus, light rail and commuter rail for emission categories, the following categories are present in my model, for both employee commuting and student commuting:

- Automobile:

  - Gasoline
  - Diesel
  - Hybrid
  - Other
- Scooter / moped
- Motorbike
- Train
- Tram
- Bus
- Metro
- Ferry

Another addition to the Campus Carbon Calculator is the presence of emissions of water usage. Finally, offsets are excluded in my model, because I wanted to focus on actual CO2 emissions of an organization.

An emission category that is not part of the Campus Carbon Calculator and not part of the Greenhouse Gas Protocol is catering. Catering could be a significant source of emissions at the EUR. However, there are two reasons why I decided not to include catering in my model. First, the CCC and the GHG Protocol do not include these in their protocol. Second, the present data is not sufficient to determine the emissions of the catering. Even if activity data of all the food that was bought in was available, then emission factors of these food products would be hard to get. To be able to exert an influence on the total emission for catering, life cycle emissions of the sold products should be known. Investments are also not part of the Campus Carbon Calculator and the GHG Protocol, although CO2 emissions of (i.e.) rebuilding can be significant emissions. In order to incorporate emissions of such investments in the CO2 footprint, more advanced standards should be created to incorporate such investments in the GHG inventory. Emissions of building projects may be allocated to different years, similar to depreciation in regular accounting.

In this paragraph I examined the different emission categories that should be present in my model for scope 1, scope 2 and scope 3. In scope 1, direct transportation sources and on-campus stationary sources should be included. Scope 2 consists of purchased heat and purchased electricity. Scope 3 contains the largest amount of categories: student commuting, employee commuting, employee travel, waste, water usage, paper usage and transmission and distribution losses of electricity. In the next paragraph, the method of calculation and choosing emission factors is discussed.

4.5 Emission factors and calculations in the model

Similarly to PAS 2050, the GHG protocol and the Campus Carbon Calculator, CO2 emissions are calculated by multiplying activity data for each (sub)category with the corresponding emission factor. The total CO2 emission can then be calculated by adding up the CO2 emissions of each category.

One reason to do this research is to provide a transparent calculation. Therefore, in this paragraph I provide an explanation of the way in which emission factors are selected for my model, and what the actual content and scope is of these emission factors.

For all the emission factors, I want the emission factors to be as specific as possible in my model. For electricity emissions, the emission does not only include emissions related to fuel combustion, but so include extracting and transporting the fuels. The situation is similar for emission factors of travelling and commuting: in addition to direct emissions that are the result of fuel use, emissions of extraction and transportation of fuels are included in the emission factor. For water, the emission factor of supplying and treating the water in the water companies is given. When it comes to paper, emissions of producing and transporting the paper are present in the emission factor that we used. Strukton (2010), the source of the paper emission factor, didn't include emissions of cutting the trees to gather the wood that was necessary for producing the paper.

When calculating emissions of electricity, transmission and distributing losses are not included in the emission factor, but are reported separately under scope 3 in the model by using a percentage of electricity that is lost during transmission and distribution. For purchased heat, heat loss during heat transfer is incorporated into the emission factor for purchased heat. However, emissions that occur before production of the heat are not included in the emission factor. The reason for this is that I acquired an emission factor from the company that supplied the heat.

4.6 Chapter Summary

In this chapter, the pros and cons of three important calculation methodologies have been discussed to see what the relevance of these models was for our research. I found that the GHG Protocol (WBCSD & WRI, 2003) is a very useful framework for calculating carbon footprints. The Campus Carbon Calculator (CA-CP, 2010) is a calculation methodology that is more specifically designed for calculating carbon footprints of universities. Although the tool has some disadvantages (the CCC is not specifically designed for CO2 emissions, it is not possible to enter the entire waste mix in the calculation sheet, not enough emission subcategories for commuting are present in the model and the documentation of the CCC is not enough to ensure full transparency of the model), the Campus Carbon Calculator will be used as the basis for my own model., because it is a very elaborate model that is specifically designed for universities. My own model contains multiple emission categories for scope 1, scope 2 and scope 3. The CO2 calculation is being done by multiplying activity data with the corresponding emission factors and then taking the sum of these multiplications for all the present categories. I tried to overcome the disadvantages of the Campus Carbon Calculator and only include the emission categories that are relevant for the EUR (e.g. emissions of agriculture are excluded in my model). In this chapter (chapter 4), I took a more general view of how my model should look like. In chapter 5, you can read how the model is exactly tailored to the EUR. A broad description is given of the data collection and what calculations are necessary to obtain suitable activity data for the calculation.

5 Case study at the Erasmus University Rotterdam

5.1 Chapter Introduction

In this chapter, the case study of Erasmus University Rotterdam is examined. A model was created by which the CO2 emission of EUR can be calculated. The CO2 emissions are calculated for the location "Woudestein". Aside from the model itself, an elaborate description of data collection and preparation is given covering all of the three scopes, as well as a brief discussion of the allocation method . After this, the results of the calculation are discussed. Also, a sensitivity analysis has been done that describes how CO2 emissions could vary when a different methodology is used. Finally, the role of information systems in calculating the CO2 footprint of the EUR is discussed.

5.2 Data collection and data preparation in the model

Collecting the required data for the calculations was a tough job. It turned out to be a real effort and it involved talking to many different people from within EUR. Data is spread throughout the whole university. There is no central system that collects and maintains data that can be useful for a carbon footprint calculation. In this paragraph, I discuss the efforts done for collecting the data. It turned out that even the simplest data is sometimes not instantly available at the university, and some data that would have been useful is not available at all. This paragraph also discusses the way in which I sometimes had to do some pre-calculations to create usable activity data for the main CO2 calculations.

5.2.1 General data of the university

Even the most basic data of the university was hard to get. Partly this is caused by the nature of the calculation: calculating the carbon footprint for 2010. Since averaged data about the amount of students, diplomas, employees and FTE is not available for a certain calendar year, I had to use estimates for these numbers. The amount of students in my calculation is the amount of students at 1 October 2010, excluding medical students. The amount of diplomas in my calculation is the amount of diplomas of the college year 2009/2010. The amount of employees is the amount of employees at 31 December 2010. The amount of FTE was measured at the same date.

Some desirable data was not available at all. I wanted to gather data on part-time and full-time students over 2010. The student administration could not give me this, even though it seems like a simple piece of information. For this reason, I did not make a separation between full-time and part-time students in my calculation.

5.2.2 Scope 1

Only two emission categories are present for this scope: direct transportation sources and on-campus stationary sources. Direct transportation sources are the vehicles that the Erasmus University Rotterdam owns. These are only two vehicles: one diesel and one gasoline vehicle. No fuel use data or kilometre data of the year 2010 was available. Only the total amount of kilometres travelled and the year of purchase was provided to me. Therefore, I estimated the amount of kilometres of the car to be $\frac{Total\ amount\ of\ kilometers\ travelled}{Years\ in\ use}$, where years in use is the amount of years that the car has been used. For on-campus stationary sources, gas was the only emission source that I incorporated here. I assumed that most of the gas was the result of furnaces; hence it was incorporated into scope 1 emissions. It was not known to me what gas the university exactly used, so I assumed that they used natural gas.

5.2.3 Scope 2

Scope 2 involves two emission categories: purchased electricity and purchased heat. For both electricity and heat, records on the use in kWh and GJ were available (although the data did not state that these were the units of measurement, I had to investigate this myself). The tougher part was getting a reliable emission factor for both of the categories. For purchased electricity, the emission factor had to be specific to the fuel mix that the university used. First, I had to figure out what the exact fuel mix was. Second, I had to calculate an emission factor that incorporated these fuel mix percentages. This was done by calculating an average (weighed) emission factor out of the different emission factors for wind, water and other green sources of energy. For purchased heat: a specific emission factor was used from the heat supplier.

5.2.4 Scope 3: commuting

Getting scope 3 activity data was the toughest job. Some data simply was not available, and had to be estimated based on other data that was present at the university. An example of this is commuting. There was no data available on the travelling distance of students and employees to the university, while the goal was to enter the total amount of km commuted by students and employees for each transportation source. Distances were estimated by using postal codes. The university did a mobility research in 2010, where postal codes were one of the questions that were asked. The tool of www.afstandberekenen.nl enabled me to calculate the distance between university and the residence of the student/employee by using two postal codes as an input. This could be done at once for an entire dataset.

The mobility research of the university also contains data about travelling behaviour of employees and students. Understandably, there was no exact data about the amount of kilometres travelled for each transportation source. This had to be estimated as well. The following travelling methods could be chosen in the mobility survey that provided me with the mobility data:

1 Car
2 Carpooling
3 Motorbike
4 Bus
5 Train
6 Tram
7 Metro
8 Train + tram/bus/metro
9 Fast Ferry

10 Bicycle
11 Scooter/moped
12 By foot
13 Public transport + car
14 Public transport + bike
15 Public transport + Fast Ferry
16 Other

Aside from the method of transport, people could indicate which fuel their car used (if they had one): gasoline, diesel, hybrid or other fuels. This categorisation enabled me to estimate the total amount of kilometres for each fuel type, resulting in more precise calculations. In the remainder of this paragraph, I explain the way in which data for each travelling method was processed to get the total amount of km for each mode of transportation.

For category 1 (see the list above), calculating the total amount of km for each mode of transportation was straightforward, except that kilometres for cars had to be attributed to one of the fuel types. This is also true for category 2. There is one difference though: carpooling means there are multiple people in the car. If there are multiple people in the car, then only a part of the emission has to be accounted for. Therefore, I divided the amount of total kilometres travelled with carpooling by two, because only half of the emissions should be attributed to one person if you assume that there are two people in the car on average.

Options 3, 4, 5, 6, 7, 9, 10 and 12 could be easily processed, because each of the methods only consist of one mode of transportation. For example, for each record that had "4" as transportation method, the estimated total km travelled was added to the "bus" category. Category 11 was also easy to be processed, as an emission factor was found for mopeds and scooters together. The only categories that remained after this, are category 8, 13 and 14. These categories consist of multiple methods of transportation.

For category eight, there are actually four possible modes of transportation: train, tram, bus and metro. I assumed that people would travel the biggest distance by train. I assumed that people went from their home town to Rotterdam Central Station by train, and then travelled from the station to the university by either tram, bus or metro. The distance from Rotterdam CS to the university is approximately 4,2 km. If someone travelled 19,2 km, then 19,2 – 4,2 km would be allocated to train travel. The remaining 4,2 km would then be distributed equally among tram, bus and metro travel, as it would be extremely hard to figure out what method of transportation would be used. This means that, for everyone that filled in category 8, 1,4 km was added to the total of these three categories: tram, bus and metro travel.

For category 13, a similar allocation key was used. I assumed that people would use their car to get to a nearby parking lot, where they would travel the remainder of the distance by tram, bus or metro. I estimated that people would travel 2,5 km with public transport on average. This decision was made arbitrarily; there was no data that resulted in my decision. For each person that chose category 13, 2,5/3 km was attributed to the categories bus, metro and tram, while the rest was attributed to "automobile".

For category 14, the assumption was that people travel to their train, bus, tram or metro station by bike and travel the rest of the distance by train, bus, tram or metro. An average of 1,5 km was taken as the distance that people would have to travel on their bikes to get to the station. The assumption was made that 40% of public transport was by train, 20% by bus, 20% by tram and 20% by metro.

The distance per transportation method was then multiplied by 2 to get the return distance, and by the amount of times that a certain person visited the university (which could also be retrieved or calculated from the data set). All the distances of the students and employees (separately) were added up to calculate the total distance travelled per transportation mode per week. I estimated that students visit the university during 40 weeks of the year, while employees are at the university during 46 weeks of the year. This estimation enabled me to calculate the estimated total km per year per transportation mode. Then I computed an average distance (km) per student or per employee for each transportation mode, by using the number of students and employees that submitted the questionnaire. This average was then multiplied by the total amount of students and the total amount of employees to get the total estimated km travelled for students and employees.

Commuting of student-assistants is not included for employee commuting, but only for student commuting. Incorporating emissions of student-assistants in employee commuting and student commuting would result in double counting.

Corrections
Several corrections had to be done for commuting. The reason for this is that my calculation methodology could result in negative kilometres in the sheet. For example, I estimated that people using bike and public transport would travel 1,5 km by bike and the rest by public transport. However, some people had a total distance of less than 1,5 km to the university, resulting in a negative amount of km for public transport. For these records, I used percentages (80% of the distance travelled was allocated to public transport, 20% by bike). Three of these corrections were necessary. About seven other corrections were necessary. Since the total amount of records was 2576 (students and employees), 10 corrections were not significant enough to make general changes to my calculations.

5.2.5 Scope 3: directly financed outsourced travel

Directly financed outsourced travel is a category where there was a huge lack of required data:

- There is no data available on the distances: only destinations are provided.
- Only one of the six faculties (ESHCC) provided information on the mode of transportation being used.
- Sometimes, multiple destinations were entered in one row. It was unclear what would be the exact route of the travel if it was done in this way.
- Sometimes cities of travel were not entered, only the countries.

In addition, quality of the data was for some faculties very low:

- Sometimes there was no standard format that was used. Sometimes the destination was entered by using the format “city,country”, sometimes “country,city”, and sometimes even other formats. This could all be in the same data sheet, making it very hard to automatically figure out what the exact country and city of a trip was

- Spelling mistakes which had to be corrected
- Multiple names could be used for a certain country, both in Dutch and English

I found a way to make the quality of the data sufficient to provide activity data for the CO2 calculations, which involved a number of steps that had to be taken. First, country and city names are usually in the same cell in Excel, separated by a comma or something else. Using the present data, I had to split such cells between “City” and “Country”. Some manual adjustments had to be done, because of spelling errors and/or different formats in which the data was delivered.

When knowing all the countries and most of the cities (some were not provided in my initial data), it was time to calculate the distances. This was not an easy job; the distance to each destination had to be calculated manually. Luckily, distance to certain destinations has been calculated before at a previous calculation. Therefore, many of the distances of these calculations could be re-used for this calculation. For the remaining destinations, the distances had to be calculated manually. For destinations in the Netherlands, France, Belgium and Germany, distances were calculated from Rotterdam to the city of destination, using the website nl.afstand.org. It was assumed that train distances are approximately equal to car distances. For other countries, flight distance from Schiphol (near Amsterdam) to the city of destination was calculated by using http://www.usatoday.com/travel/flights/miles/calculator.htm. If a certain destination was not available, then it was calculated at nl.afstand.org, using the direct route method (which assumes that the distance is travelled in a straight line). In addition, it has been estimated a few times (before discovering nl.afstand.org) by using the distance to a different city in the same country. Also, there is some inconsistency in the way distances were calculated for certain cities, because the person who previously computed distances (which I copied if possible) used a slightly different method.

Since the method of travel for most of the destinations was not given, I had to make certain assumptions. I assumed that all travel in the Netherlands (only 1 record), Germany and Belgium was done by train. For France, I assumed that all travel to Lille and Paris was done by train. For all other destinations in France, the estimation was that 60% of the travel goes by train and 40% by plane. Furthermore, I assumed that 80% of the travels to the UK were by plane and 20% by train. Kilometres of travels to other countries are all allocated to air travel.

Of course the distances are not entirely correct when this arbitrary allocation to train and plane takes place. For example, for the calculation of the distances for France I assumed that train is the method of transportation, even though afterwards part of the total kilometres travelled to certain destinations in France are allocated to air travel. The reason that I used this approach is that it would be too much work computing distances for train and air travel separately, when both modes of transportation are possible for a certain country.

Sometimes multiple destinations were present in one record. I then tried to compute the distance from Schiphol to the nearest destination, then to the destination that is nearest to the first destination, etc. I made this assumption, because the actual routes were unknown. There were four records where a whole route was described to a certain place in the UK. For these distances I made an exception, because the distances were relatively small; I only calculated the distance to the final city of destination, instead of making calculations for an entire route.

When only a country was entered in the data sheet, I took the distance to a random city in this country (usually the capital). After computing all the distances and performing the allocation to train and air, I distinguished kilometres long (non-European) flights from shorter (European) flights, because I wanted to use different emission factors for short and long flights. After doing these calculations, the kilometres travelled were all added up to calculate the total amount of km travelled by train, European air travel and non-European air travel.

5.2.6 Scope 3: other emission categories

The other emission categories of scope 3 are waste, water, paper and electricity T&D losses. Gathering data for water use was the easiest; this was present in the same Excel file as electricity and heat. For electricity T&D losses, the data for electricity consumption (same data that was used for scope 2) was used. Waste data was obtained among different categories. The data file was not very clear (units of measurement were sometimes not given), and certain calculations had to be done. Four categories required further calculations.

For example, no data about the weight of glass waste was present in the data sheet. Instead of that, data about the amount of containers and the amount of litres that could fit into the containers was present. 240 litres could be present in one container. I then estimated that this 240 would contain 30 litres of glass. The density of glass is about 2,5 kg/l, so one full container has approximately 30 * 2,5 = 75 kg of glass in it. Similar calculations were done for the burning of confidential paper.

Emissions of swill waste are not incorporated in the calculation, because I did not know how to make an estimation of the total amount of swill that was processed. A reliable density factor could not be found, and I did not have data on the size of the swill containers.

For paper, data came from two sources. First, the EFB (Erasmus Facilitair Bedrijf) gave me a data sheet which contained the paper purchased and their corresponding weights (kg). The Copyshop of Service Point did not give me data of such quality; instead they gave a me an estimation of the amount of sheets that were used in 2010. Using the estimated amount of sheets, I estimated the total weight of these sheets. This number was added to the total weight of the EFB data to serve as the activity data for the calculation.

5.2.7 Overview of emission factors

In the previous sub-paragraphs, some information about the gathering of emission factors has already been given. In this sub-paragraph, an overview is given of the eight different sources that are used for finding emission factors. First, the manual of the "CO2Prestatieladder" is used (ProRail, 2010). The CO2 Prestatieladder is a method of assessing the maturity of a company's CO2-policy, based on the Capability Maturity Model (CMM). Several levels are described, from no measuring and no reduction programmes to standardized measurement and an emission reduction program. The CO2 Prestatieladder is not a calculation method; therefore it was not discussed in the literature review. However, it provided some useful emission factors, which were used for the calculation in this research.

The second source often used for emission factors is the document of Den Boer et al. (2008). This document is specifically dedicated to CO2 emission factors for transport. The document by DEFRA (2010) is an English government document, describing several emission factors that companies can use for a variety of different emission categories.

The other five sources were all used to get an emission factor for one specific emission category: the document by Strukton (2010) was consulted for the emission factor of paper, the publication of Hackett and Gray (2009) was used to get the emission factor of water and the emission factor from the book of Hermans (2008) was used for the emission factor of natural gas. Van Gansewinkel (2011), the company that processes Erasmus University Rotterdam's waste has their own document, which displayed reductions relatively to the standard emission factor for incineration of waste. Van Gansewinkel emailed me the standard emission factor to be able to estimate the emission factor of all the different waste processes. Finally, the emission factor of the heat provided by Eneco was not gained from a publication, but was emailed to me. Below, an overview of the emission factor sources can be found:

	Emission category	Source of the emission factor(s)
Scope 1		
	On-campus stationary sources	Hermans (2008)
	Direct transportation sources	ProRail (2010)
Scope 2		
	Purchased electricity	ProRail (2010)
	Purchased heat	Email of Eneco
Scope 3		
	Employee commuting	Den Boer et al (2010), ProRail (2010), DEFRA (2010)
	Student commuting	Den Boer et al (2010), ProRail (2010), DEFRA (2010)
	Employee travels	ProRail (2010), DEFRA (2010)
	Water usage	Hackett and Gray (2009)
	Paper consumption	Strukton (2010)
	Waste	Van Gansewinkel (2011)
	Electricity T&D losses	ProRail (2010)

Table 2: Emission categories and the sources of the emission factors

In this paragraph, the way of collecting and preparing data was discussed. Scope 2 data was easy to retrieve; no calculations were necessary to get the right activity data for scope 2. However, gathering and preparing data for scope 1 and 3 took a lot of time. Data is dispersed throughout Erasmus University Rotterdam. Many people had to be contacted to get the data. Sometimes the right activity data was not available. Therefore, some calculations had to be made to estimate the values of the activity data.

5.3 *Allocation in our model and results of the calculation*

5.3.1 Calculation method

The calculation method used is already described previously in this document. The data that was gathered and prepared is entered as activity data in the data sheet. Activity data for each category is multiplied with the corresponding emission factor. All these multiplications are then added together to get the total CO2 emission of the Erasmus University Rotterdam.

5.3.2 Allocation of CO2 emissions in the model

In the model, CO2 emissions are allocated between research and education for most categories, with the exception of employee travel (research only) and student commuting (education only). For allocation, the following allocation key is used. The EUR states that their employees spend 40% of their time on education and 60% on research. Therefore, for each category where allocation is necessary, 40% of the emissions are allocated to education and 60% are allocated to research.

Whether these allocations are representing the true emissions of education and research could be questioned. There are many lecture halls in the university, which are used for education purposes only. Therefore, allocating only 40% of building emissions to education may not be enough. The same may be true for waste, because at most times there are probably more students than employees present at the university. In the sensitivity analysis I examine what would happen if I used different percentages for these categories. The sensitivity analysis is described in paragraph 5.4.

Allocation could have been done in a more accurate way, for example if the university would measure the total area of lecture halls and the total area of all the office rooms together. Using this information, an allocation key could be developed to allocate emissions of heating. Different methods of allocation are discussed in chapter 6.

At the start of this research, the plan was to calculate CO2 emissions for different faculties. However, while trying to do this, I discovered that it is very hard and time-consuming to allocate emissions to faculties in the case of EUR. Furthermore, most faculties do not have an environmental policy, but follow the central orders of the university. Employee travelling is the only emission category where reliable data is available that is separated between different faculties. More about this issue is discussed in chapter 6.

5.3.3 Results of the calculation

The results are presented for similar categories and subcategories as in the Campus Carbon Calculator (CA-CP, 2010). However, for my model, CO2 emissions are reported in a more elaborate way. In the table below, the results of the calculation are visible. CO2 emissions are reported for each subcategory in terms of research emission, education emission, total emission in kg and total emission in percentages:

Scope	Emission category	Research CO2 emission kg CO2	Education CO2 emission kg CO2	Total CO2 emission kg CO2	Total CO2 emission %
	On-campus stationary sources	8.189	5.460	13.649	0,11%
Scope 1	Direct transportation sources	799	532	1.331	0,01%
	Purchased electricity	552.097	368.064	920.161	7,30%
Scope 2	Purchased heat	953.145	635.430	1.588.575	12,61%
	Employee commuting	996.388	664.259	1.660.647	13,18%
	Student commuting		7.763.420	7.763.420	61,61%
	Employee travels	336.988		336.988	2,67%
	Water usage	30.185	20.123	50.309	0,40%
	Paper consumption	44.779	29.853	74.631	0,59%
	Waste	65.295	43.530	108.824	0,86%
Scope 3	Electricity T&D losses	49.689	33.126	82.815	0,66%
	Total	3.037.553	9.563.797	**12.601.349**	100,00%
	Total per student*		521	521	
	Total per diploma*		1.669	1.669	
	Total per employee	1.217	3.833	5.051	
Totals	Total per FTE	1.611	5.073	6.684	

Table 3: Results of the CO2 footprint calculation

* For emissions per student and per diploma, research emissions are not part of the total. I believe emissions of research should not be allocated to students, because they are here for education.

12,6 million kilograms of CO2 was emitted in 2010 according to this calculation. 9,6 million kg is allocated to education, while 3,0 million kg is allocated to research. This big difference can be explained by the presence of student commuting in this calculation, which is 61,6% of the total CO2 emission of the university.

The total CO2 emission per employee is much higher than the total CO2 emission per student. This is quite logical. First, there are more students than employees, so the total CO2 emission can be allocated to more people in the case of students. Second, for the CO2 emission per employee, both research and education emissions are included in the calculation. Only CO2 emissions of education are included for students.

Scope 1 emissions are quite insignificant compared to the rest. This can be explained because the EUR does not produce their own electricity and heat, and they do not own a lot of company vehicles. Scope 2 emissions are more significant, although not that high, since the EUR uses green power resulting in a low emission. For heat, “Stadsverwarming” by Eneco is used, which also reduces CO2 emission, compared to heating in a boiler.

Scope 3 emissions are, by far, the largest source of CO2 emissions. This is mainly because of the high emissions of commuting. Student commuting is 61,6% of the total CO2 emission of the university, and employee commuting 13,1%. The fact that emissions of student commuting are much higher than employee commuting is because there are more than seven times as many students as employees.

Emissions of employee travel (mostly consisting of flight travel) are lower than I expected percentage-wise. Paper and water emissions are quite low, compared to other CO2 emissions. I already suspected that emissions of water would not be that high, because the Campus Carbon Calculator did not include it in their model. However, data about the amount of water consumed was very easy to obtain, and emissions of water usage is still 0,4% of the total CO2 emission. It should be noted that the percentage of emissions of waste and paper would have been higher if other GHG emissions would have been incorporated in the calculation, as was discussed in paragraph 4.3.

To summarize this paragraph: the university emitted about 12,6 million kilograms of CO2 in 2010. Commuting is by far the largest source of CO2 emissions. Purchased heat and purchased electricity are also large sources of CO2 emissions. All other emission categories have a CO2 emission of less than 3% of the total CO2 emission of the Erasmus University Rotterdam. In the sensitivity analysis I examine what the results would be if CO2 was calculated in a different way, by using several scenarios.

5.3.4 Comparison with other calculations

The results of Erasmus University Rotterdam for 2010 can be compared with other universities. In this paragraph, I compare the results of Erasmus University Rotterdam to two other universities, as described in paragraph 4.3. Below a table can be found which displays the result of the comparison between Erasmus University Rotterdam (EUR) the University of Toronto, St. George Campus (UoT) and Lakeland Community College (Lakeland). Not all emission categories are incorporated in the table, but only the most important ones. All the numbers are stated in kilogram CO2. “Times a week” means the average number of times that someone comes to the university in one week, “weeks per year” the (average) amount of weeks that a person is present at the university, while “% car commuting” is the estimated percentage of kilometres that is travelled by car. Data that I use in the table is gained (or calculated) from the report of the UoT (University of Toronto, 2010) and the report of Lakeland Community College (Lakeland Community College, 2009). In this table, one difference is present with regards to emissions per student. In table 3, emissions per student only included emissions of education. In the table below it includes all emissions, because for Lakeland and UoT, no separation was made between research and education.

		EUR	UoT	Lakeland
Amount of employees	Total	2.495	11.825	679
Amount of students	Total	18.366	53.957	9.335
Average distance to uni	Students	19,6	8,2	23,9
	Employees	23,9	8,6	20,9
Times a week	Students	3,3	5,0	3,0
	Employees	3,4	5,0	4,0
Weeks per year	Students	40,0	32,0	45,0

	Employees	46,0	44,5	45,4
% car commuting	Students	13,09%	12,00%	98,00%
	Employees	35,84%	40,00%	100,00%
Student commuting	Total	7.763.419,9	18.541.346,0	14.608.903,6
	Per student	422,7	343,6	1.565,0
Employee commuting	Total	1.660.646,9	8.301.167,0	1.251.749,2
	Per employee	665,6	702,0	1.843,5
Employee travel	Total	336.987,7	1.366.469,0	779.515,0
	Per employee	135,1	115,6	1.148,0
Purchased heat	Total	1.588.574,7	5.085.473,0	-
	Per student	86,5	94,3	-
	Per employee	636,7	430,1	-
Purchased electricity	Total	920.161,2	48.731.344,0	7.310.881,4
	Per student	50,1	903,2	783,2
	Per employee	368,8	4.121,0	10.767,1
Co-generated electricity	Total	-	13.315.510,0	-
	Per student	-	246,8	-
	Per employee	-	1.126,0	-
Co-generated heat	Total	-	13.314.955,0	-
	Per student	-	246,8	-
	Per employee			
Other on-campus stationary sources	Total	13.648,8	56.355.720,0	2.365.046,8
	Per student	0,7	1.044,5	253,4
	Per employee	5,5	4.765,8	3.483,1
Total	Total	12.601.349,2	160.772.585,0	26.442.412,0
	Per student	686,1	2.979,6	2.832,6
	Per employee	5.050,6	13.596,0	38.943,2

Table 4: comparison of emissions between three universities.

First I compare the results of the EUR with the results of the University of Toronto, St. George Campus (University of Toronto, 2010). For the University of Toronto, scope 1 emissions were more than 50% of the total CO2 emissions, while for EUR, emissions of scope 1 are only about 0,12% of the total CO2 emission. The reason for this high number is that the University of Toronto (UoT) produces part of their electricity and heat themselves. In addition, some of the steam and electricity is generated for facilities that are not under the university's control. This is a limitation of the Campus Carbon Calculator; it is not visible how much electricity and steam was transferred to other facilities that are out of the control of the University of Toronto. About one third of the total CO2 emission contains scope 2 emissions at the UoT: purchased electricity, purchased heat and purchased steam.

Scope 3 emissions are, unlike for EUR, the least significant source of emissions for the UoT. However, just as for EUR, student commuting and employee commuting are the main sources of scope 3 emissions. For EUR, the average student commuting emission is 423 kg CO2/student/year. For the University of Toronto it is 344 kg CO2/student/year for student commuting. For employee commuting, the average employee commuting emission is 666 kg CO2/employee/year for EUR, vs. 702 kg CO2/employee/year for Toronto. There are two main reasons why the student commuting emissions for the UoT are a bit lower than the emissions of EUR. First, the average distance to the university is significantly higher for people at EUR. Second, students spend more weeks per year at the university at the EUR, when compared to

UoT. For employee commuting, emissions are a bit higher for UoT, despite the much larger distance that employees have to travel to get to the EUR. There are three main explanations for this. First, emission factors used in my model are lower than the emission factors used in the Campus Carbon Calculator. Second, employees at UoT are present more often at the university than their Dutch colleagues. Third, the car is more often used at the UoT.

Scope 1 and 2 emissions, which are emissions of purchased and co-generated heat, purchased and co-generated electricity and other on-campus stationary sources, are much higher for the UoT than for Erasmus University Rotterdam. There are multiple possible explanations for this. First, probably no green electricity is used at UoT, because I could not find any text about this in their report. Second, heating may also be less environmental friendly at UoT when compared to the EUR. The EUR uses "Stadsverwarming", which uses heat that is the result of electricity production. This has a lower CO2 emission than regular purchased heat. Third, some electricity and heat that is produced goes to facilities that are not controlled by the UoT. Fourth, the temperature in the winter is in Canada much colder than in the Netherlands. The higher total CO2 emissions per student and per employee for UoT are the result of the fact that scope 1 and scope 2 emissions are much higher for UoT.

The distribution of emissions among the different emission categories at the EUR is more similar to Lakeland Community College than to the UoT. Lakeland Community College is a community college in Lakeland in the state Ohio in the USA, with about 9335 students per year. Part-time students are counted for 50% in this number (Lakeland Community College, 2010). Here, student commuting is about 55% of the total CO2 emission, which is quite similar to the 62% of EUR. Employee commuting is only about 5% of the total CO2 emission, which is substantially lower than the 13% of EUR. However, student commuting emissions are 1565 kg CO2/student/year, and employee commuting emissions are 1844 kg CO2/employee/ear, which is significantly higher than for the EUR and the University of Toronto. A possible explanation for this is that almost everyone uses the car to get to Lakeland Community College (LCC). LCC estimated that 98% of the students travel by car to Lakeland, and 100% of the staff. Emission factors for cars are much higher than for public transport (which is more commonly used at EUR). In addition, the Campus Carbon Calculator uses higher emission factors for cars. These reasons combined result in a higher CO2 emission for commuting.

Electricity emissions of Lakeland Community College are percentage-wise higher than for Erasmus University. Electricity comprises more than 27% of the total CO2 emission for Lakeland, vs. only 7% for EUR. This can be explained by the fact that LLC probably does not use green electricity. LLC does not include purchased heat in their calculation. However, "other on-campus stationary sources", which are on-campus stationary sources that are not a part of co-generated electricity or co-generated heat, are the 2nd largest emission category for Lakeland. Despite the fact that the EUR has a lot more students and employees, emissions of "other on-campus stationary sources" at LLC are bigger than the emissions of purchased heat and electricity at the EUR added together. At least part of the other on-campus stationary sources should generate heat, because LLC does not purchase heat. However, the percentage of other on-campus stationary sources that produce heat is not visible in the report of Lakeland Community College.

These comparisons show that the EUR saves CO2 emissions, due to their green electricity. Furthermore, the way heat is provided (by using "Stadsverwarming") has also reduced CO2 emissions for the EUR. Other universities that do not have electricity and heat that is produced in an environmental friendly way emit more CO2. Because of the savings in heat and energy, commuting has become the most significant source of CO2 emissions (percentage-wise) over the years for the EUR. The EUR could use this result if they want to create a policy that is aimed at reducing CO2 emissions.

5.4 *Sensitivity analysis*

Several scenarios analyses have been done to determine what would be the results if a different calculation methodology was used. In each of the four next sub-paragraphs, one or more alternative scenarios are reviewed to see what the impact of a different calculation method would be on the CO2 emissions of the university.

5.4.1 Excluding student commuting emissions

Table 2 shows that emissions of student commuting amount to 61,6% of the total CO2 emissions of the Erasmus University Rotterdam. Before doing the calculation, I actually doubted whether I should include student commuting in my model. The reason for this is that student commuting is not organized by the university and is hard to be controlled by the university. In the end I decided to include it anyway, because the university would not be there without the students who travelled there every day, and the university can exert at least a little influence on the travelling behaviour of students. Still I figured it would be interesting to find out what the impact would be if I removed student commuting from the Excel sheet. The table below shows the results without student commuting:

Scope	Emission category	Research CO2 emission kg CO2	Education CO2 emission kg CO2	Total CO2 emission kg CO2	Total CO2 emission %
Scope 1					
	On-campus stationary sources	8.189	5.460	13.649	0,28%
	Direct transportation sources	799	532	1.331	0,03%
Scope 2					
	Purchased electricity	552.097	368.064	920.161	19,02%
	Purchased heat	953.145	635.430	1.588.575	32,84%
Scope 3					
	Employee commuting	996.388	664.259	1.660.647	34,33%
	Employee travels	336.988		336.988	6,97%
	Water usage	30.185	20.123	50.309	1,04%
	Paper consumption	44.779	29.853	74.631	1,54%
	Waste	65.295	43.530	108.824	2,25%
	Electricity T&D losses	49.689	33.126	82.815	1,71%
Totals					
	Total	3.037.553	1.800.377	**4.837.929**	100,00%
	Total per student*		98	98	
	Total per diploma*		314	314	

	Total per employee	1.217	722	1.939	
	Total per FTE	1.611	955	2.566	

Table 5: The results if student commuting is not included in the calculation

The first thing that comes to mind is that the emission allocated to research is now much higher than the emission allocated to education. In the main calculation, it was the other way around. The reason for this shift is that student commuting is entirely allocated to education.

Since student commuting was more than 60% of the total emission of the university, it shows that the percentages of all the emission categories are more than 2,5 times as high when student commuting is removed. Total CO2 emissions of the university are more than 2,5 times as low. This means that, when doing calculations, universities have to make an important decision on whether to include student commuting or not, because it influences the calculation to a large extent. If the university wants to start a certain initiative (for example reduce emissions of heating), then this would have a much larger effect if student commuting is not a part of the calculation (percentage-wise). Therefore, it may be interesting for universities to remove student commuting from the calculation, as it is a category that is hard to influence. Still, I believe student commuting should be part of the calculation, for the reasons I mentioned before.

5.4.2 Different allocation keys for research and education

In the main calculation, I used an allocation rate of 60% for research and 40% for education if emissions of a certain category had to be allocated. This is an allocation rate that is based on the fact that the Erasmus University Rotterdam states that their employees spend 40% of their time on education and 60% on research. However, I wanted to see what the influence would be of using different methods of allocation. Four scenarios are considered:

- The base scenario of 60% research and 40% education
- 50% research and 50% education
- 70% research and 30% education
- A scenario of 60% research and 40% education, with the following exceptions:
    - Purchased heat (70% education and 30% research)
    - Waste (70% education and 30% research)

There is of course a reason for including the last scenario; I think there are usually more students in the university than employees. Since students are at the university for education, there could be more emissions allocated to education than to research, because I assume that 1 student needs as much heat as 1 employee. The same reasoning is there for waste. Below, the results of the analysis can be seen:

Scenario	Research emission kg CO2	Education emission kg CO2	Total CO2 emission kg CO2
Base scenario (60r, 40e)	3.037.553	9.563.797	12.601.349
50% research, 50% education	2.587.459	10.013.891	12.601.349
70% research, 30% education	3.487.647	9.113.702	12.601.349

Purchased heat and waste change	2.528.333	10.073.016	12.601.349

Table 6: Comparison of emissions between different allocation keys for research and education

For the 50% research and 50% education scenario and for the purchased heat and waste change scenario, about 0,5 million kg of CO2 moves from research to education. Similarly, when 70% of the CO2 emissions would be allocated to research and 30% to education, then there would be a change of about 0,5 million kg CO2 that goes from education to research.

0,5 million on a total of 3,0 million kg of CO2 for research is a change of approximately one sixth. This is quite significant. However, it could be expected to be more significant, considering the change in percentages that is quite high. The explanation that the differences between the base scenario and the other scenario's are only approximately 15% is that emissions of student commuting (the biggest source of CO2 emissions) are allocated entirely to education. This does not change with changing these allocation percentages.

5.4.3 Different allocation methods for employee travel

Due to an incomplete dataset, I often did not know how people travelled. I made the following assumptions when allocating certain travels to train and air:

- People travel by train to Belgium, Germany and destinations within the Netherlands
- People travel by train to Lille and Paris. For other destinations in France, 60% is by train and 40% by air.
- To England, 80% of the journeys are by airplane, the rest is by train.
- People travel to all other destinations by airplane

In this subparagraph, I examine what would be the influence on employee travel emissions if the scenario is a little bit different. I compared the following two scenarios with the base scenario:

- People travel to England and France only by train
- People travel to England and France only by airplane. In addition, 50% of the trips to Germany is by airplane

The following table displays the results of this analysis:

	Employee travel CO2 emission	
	Emission kg CO2	Emission Compared to base
Base	336987,7	0
More train	334975,9	-0,60%
More air	340067,4	0,91%

Table 7: Comparison between different methods of allocating emissions of travel within Europe to train and air

The differences between the base scenario and the two other scenarios are less than 1%. The two scenario's represent two extreme scenario's which do not cover reality. If even these scenario's would cause less than a 1% change in CO2 emission of employee travel, then I assume that the method of allocating emissions to air and train for business travel does not significantly influence the total CO2 emission of employee travels.

5.4.4 Commuting calculation

The last topic in the sensitivity analysis to discuss is the calculations for student commuting and employee commuting. Student and employee commuting together amount to about 75% of the total CO2 emission of the university. Therefore, it makes sense to check what the influence could be of a different way of calculating emissions for commuting.

Luckily, the dataset for commuting was quite extensive, which allows calculating emissions of commuting in a fairly accurate way. The thing that offers the most freedom in the calculations is when people are allowed to enter multiple modes of transportation. It is then unknown what the exact modes of transportation are; it is unknown how many km people travel with each transportation mode. The following options were available in the survey where people could enter multiple modes of transportation (see sub-paragraph 5.2.4):

1. Train + tram/bus/metro
2. Public transport + car
3. Public transport + bike
4. Public transport + Fast Ferry

Option 4 was never used, so only the impact of the choices of options 1 – 3 is assessed here. For my main calculation, the following methods were used to allocate emissions to the different travelling modes (each number corresponding to one of the scenario's above):

1. 4,2 km by tram, bus or metro (4,2 / 3 = 1,4 km for each mode on average), the rest of the distance by train.
2. 2,5 km by public transport (bus, tram or metro, 2,5 / 3 km for each mode on average), the rest of the distance by car.
3. 1,5 km is travelled by bike, the rest of the distance is travelled by public transport (40% train, 20% metro, 20% bus, 20% tram).

This is the method that was used in the main calculation, the base method. An alternative method may also be used. I chose to examine the influence of a method that was based on percentages of the total distance travelled, instead of absolute numbers. The following method was used for calculating emissions of the alternative scenario:

1. 75% of the distance is travelled by train, 25% of the distance by tram, bus or metro. The total distance allocated to tram, bus and metro is than spread equally among these three transportation modes.
2. 75% of the distance by car, 25% of the distance by tram, bus or metro. The total distance allocated to tram, bus and metro is then spread equally among these three transportation modes.
3. 80% of the distance is travelled by public transport (40% by train, 20% metro, 20% bus, 20% train), the rest of the distance is travelled by bike.

When the emissions of the alternative scenario are compared to the base scenario, the following are the results:

	Employee commuting kg CO2	Student commuting kg CO2	Total commuting kg CO2
Alternative	1644966,664	7703493,191	9348459,855
Base	1660646,917	7763419,851	9424066,768
Alternative - base	15680,25304	59926,66027	75606,9133
% difference	1,0%	0,8%	0,8%

Table 8: Comparison of emissions between two ways of calculating the CO2 emissions of commuting

As table 8 shows, the commuting emission for the alternative scenario and the base scenario differ about 1%. This shows that the way in which the kilometres are allocated can definitely change the total CO2 emission of the university. As said before, about 75% of the total CO2 emission of the university has commuting as its source. If there is already a deviation of 0,8% between these two scenario's, then it proves that the calculation of CO2 emissions for commuting is at least a little bit subjective. Therefore, more information about the exact routes of students would improve the CO2 calculation.

5.4.5 Overview of uncertainty

The table below provides an overview of the different emission categories of my model, the method of gathering the data and the corresponding level of uncertainty. I have used four different types of symbols to indicate the level of uncertainty in the table below:

- M: the activity data is measured. This is the level with the least uncertainty
- C1: the activity data is calculated and uncertainty is low
- C2: the activity data is calculated and uncertainty is medium
- C3: the activity data is calculated and uncertainty is high

Scope	Emission category	Method of collecting/calculating the activity data	Uncertainty
	On-campus stationary sources	The amount of gas was measured	M
Scope 1	Direct transportation sources	Dividing the total amount of km travelled by each car by the estimated age of the car (based on the year that the cars were bought). Then summing the estimated km for both of the cars up	C2
	Purchased electricity	The amount of purchased electricity was measured	M
Scope 2	Purchased heat	The amount of purchased heat was measured	M
Scope 3	Employee commuting	The distance between the university and each employee was calculated by using a tool that estimates travelling distance, based on two ZIP	C2

		codes (employee ZIP code and university ZIP code) In the survey, employees could fill in their mode of transportation. Based on this, the estimated travelling distances was allocated to a transportation mode. Sometimes multiple modes of transportation were filled in. Based on an estimation, the estimated distance per trip was allocated to different transportation modes The estimated total distance (km) was calculated over an entire year for each transportation mode over the total of 1028 employees that filled in the survey This distance was then used to estimate the total travelled distance of all the employees (2113)	
	Student commuting	Same method as for employee commuting. 1548 students filled in the survey. This data was used to estimate the total travelling distance of 18366 students	C2
	Employee travels	Data sheets with all the travels and their destinations were gathered from the faculties. Distances to the destinations were not part of the data sheets. Distances were then estimated by using tools on the internet, or the estimations of the distances that were used for a previous CO2 calculation of EUR For almost all of the data, the transportation mode was not given. Therefore, rules were set up to allocate distances to train and air, based on the travelling destination. Flight distances were allocated to European to Non-European air travel, based on the destinations. The total flight distances and train distance are calculated by adding up all the distances from the individual travels.	C2
	Water usage	The water usage was measured	M
	Paper consumption	Two sources of data were used for paper consumption: purchasing data from the EFB (Erasmus Facilitair Bedrijf) and data from the Service Point Copyshop. The EFB data contained the total weight of the purchased paper. The Copyshop only gave me an estimation of the amount of sheets that they used in one year. This amount of sheets was used to	C2

		estimate the total weight of the Copyshop paper. This estimation was added to the total weight of the purchased paper of the EFB to get the estimated total paper consumption for EUR	
	Waste	Activity data was necessary for residual waste, paper and cardboard, confident paper and glass. For residual waste and paper and cardboard, the total weight was known. For confident paper and glass (a small proportion of the total waste), only the volume and amount of containers that were processed by Van Gansewinkel (company that processes waste) were known. The volume, the amount of containers, the estimated proportion of glass and confident paper of the container (part of the container is filled with air) and the density of paper and glass was used to estimate the total weight of the confident paper and glass waste. Swill waste is not included in the calculation, because the available data was not sufficient	C3
	Electricity T&D losses	T&D losses were calculated based on the electricity usage, which was measured. However, the percentage of electricity that was lost during transmission and distribution was estimated.	C2

Table 9: Emission categories, the corresponding method of getting the activity data and the related uncertainty

Direct transportation has a C2 level of uncertainty, because there is no data about the amount of travelled km per year, and no data about the exact date of purchase. On the other hand, the total amount of distance travelled was measured. For these reasons, the uncertainty was set as "medium".

For employee and student commuting, the travelling distance from home to work (and home to study) are reasonably accurate, because they are based on Google Maps calculations and postal codes. On the other hand, it was sometimes not known how many kilometres were travelled with each transportation mode, due to the answer possibilities of the survey. The difference between the calculated CO2 footprints between the 2 scenario's in the sensitivity analysis was 1%. Therefore, I believe labelling commuting as "medium uncertainty" would be correct.

Employee travel also has a C2, medium uncertainty, as the uncertainty level of the calculated data. The distances are also calculated by using a tool, distances also sometimes had to be allocated to different modes of transportation, and the differences between different scenario's were also approximately 1%.

For paper consumption, part of the weight of the paper was measured, and part was estimated. Even though most of the weight was measured, the part that was not measured is very inaccurate. The total amount of consumed paper of Service Point was not even known, nor was the weight of the paper known. Therefore, I believe medium uncertainty would be a good label.

Finally, for waste, most of the weights were measured. However, a proportion was calculated; for confident paper and glass, only the size of the containers and the amount of containers were known. Estimating the waste for these waste categories creates a lot of uncertainty, because there is no way to reliably estimate the proportion of the volume of the container that was filled with glass or confident paper (instead of air). Furthermore, the size of the swill containers was not known, and the density of swill waste has not been found. Therefore, swill is not included in the waste calculation. Because of the uncertainty for confident paper, glass and swill, I believe high uncertainty is the correct label for waste.

I used the uncertainty of each emission category and the percentage of the total CO2 emission of the corresponding emission category to see what the average uncertainty was. Each uncertainty category (M, C1, C2, C3) corresponds to multiple emission categories. For each uncertainty category, a sum was calculated of the percentages of the total CO2 emission for each emission category that has that level of uncertainty. This percentage can be found for each uncertainty category in the table below:

Uncertainty	Percentage of total CO2 emission
M	20,42%
C1	0,00%
C2	78,72%
C3	0,86%

Table 10: Uncertainty categories and the corresponding CO2 emissions

The emission categories with uncertainty "C2" contribute to more than ¾ of the total CO2 emission of the university. Therefore, I conclude that my activity data has medium uncertainty on average.

5.5 Information systems

A part of this research is to examine the extent to which ICT can aid in calculating the carbon footprint of a company. For this, I did two interviews. The first interview was with Robbert Jacobs of SAP. The Erasmus University Rotterdam uses the ERP system from SAP, so I wanted to discuss the possibilities of calculating the carbon footprint with SAP with Robbert Jacobs. After having the interview with Robbert Jacobs, I wanted to investigate whether measuring the carbon footprint with SAP would be desirable and attainable for the EUR. That is why I interviewed Marcel Hoornweg at the EUR.

In this paragraph, the most important results of both interviews are discussed. It is important to know that the text in paragraph 5.5 describes the opinion of the interviewees (unless stated otherwise), which is not necessarily my own opinion. In the discussion (chapter 6), my own opinion is added to the subject.

5.5.1 Interview Robbert Jacobs – SAP

At SAP, I interviewed Robbert Jacobs, whose function is "Industry Principal Manufacturing". SAP is very busy with sustainability. They are trying to reduce their emissions by 5% each year. SAP has its own software for calculating carbon footprints: Carbon Impact. With Carbon Impact, emissions of certain buildings or organizations can be calculated, in terms of CO2, CO2 equivalents and more types of emissions. Using Carbon Impact, reporting can be done. It is possible to display the amount of CO2 that is emitted per employee or per square feet, in which country they emit the most CO2, etcetera. Carbon Impact is not part of an ERP system, but it can be connected to the SAP ERP system. For calculating the footprint, multiple protocols can be selected in Carbon Impact, including protocols of WRI and IPCC. In the picture below, CO2 emission of SAP is displayed per category by using SAP Carbon Impact:

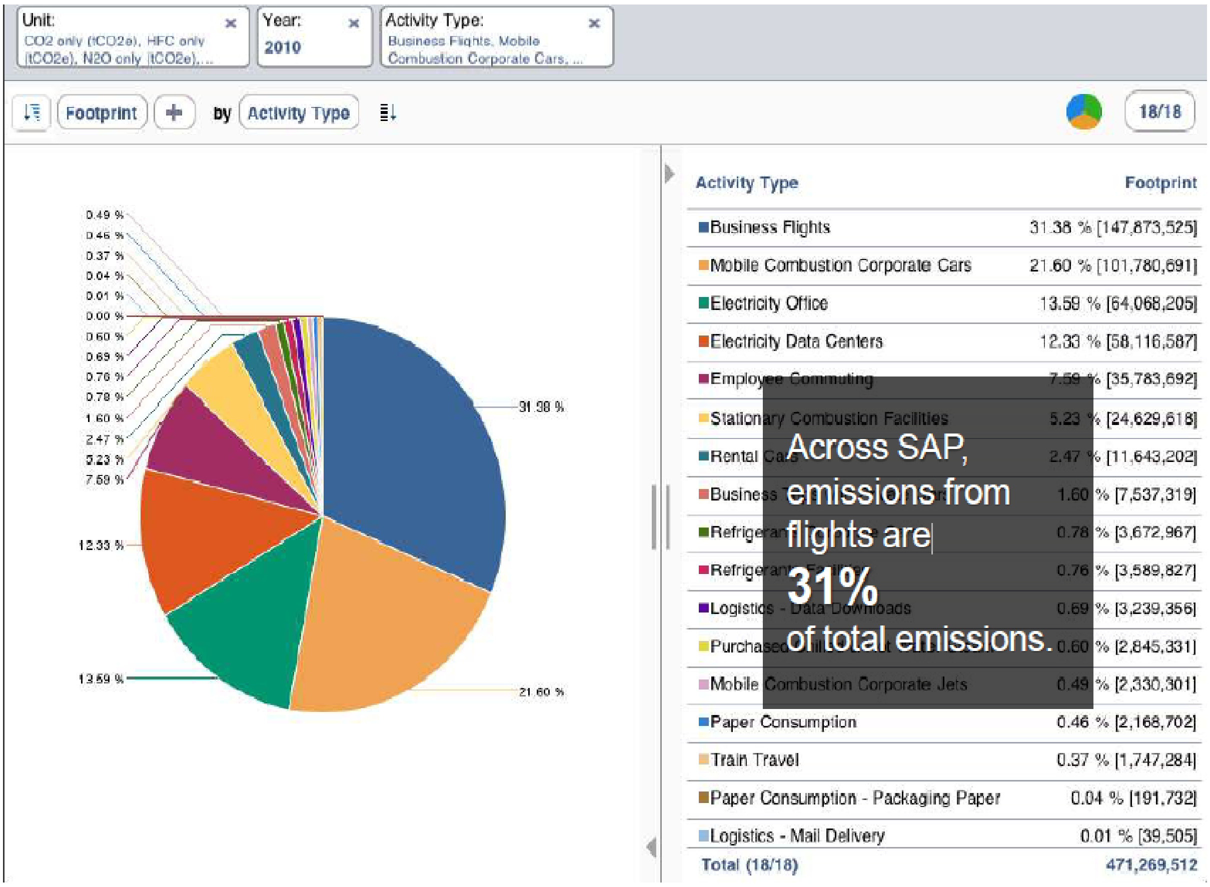

Figure 7: CO2 emission per category by SAP Carbon Impact

There are basically three ways of collecting data with Carbon Impact:

- Enter the data manually
- Automatically, using interface protocols. Some examples:
  - Automatic import (interface) for Excel documents
  - Interface based on web services
- Survey's

Carbon Impact can be used in combination with the SAP ERP system. This means that certain data that is present in other places in the organization may be used for doing carbon footprint calculations. For example, if one system registers the purchasing of paper, then the X kg of paper purchased can be used to calculate the CO_2 emissions of producing that X kg of paper. It is possible to retrieve most of the required quantitative data from a SAP system.

Robbert Jacobs recommends that organizations start using Carbon Impact, even when the desired connections between all the databases are not yet established. Using Carbon Impact shouldn't be too much of a transition when this approach is used. More manual data or surveys may have to be used more in the beginning. Connections between databases can then be established at a later phase.

Robbert Jacobs recommends allocating emissions based on an allocation key that covers multiple aspects. For example, emissions of a building may be allocated to certain faculties, based on the office space of the faculty in a certain building, and the number of people of a faculty in that building. Using only one variable to allocate emissions may result in inaccurate allocations. SAP Carbon Impact allows certain emissions to be allocated.

When it comes to verification, Carbon Impact can help verifying the correctness of the data. For example, when someone is filling in a survey, then an Excel sheet may be added to the survey. This can be stored, so that people can see the source of the data when required.

In this interview, it became clear that there are possibilities for Erasmus University Rotterdam to calculate their carbon footprint by using more advanced tools than the Excel sheet that I have been using. Integration with different databases is possible to (partly) automate the footprint calculation. However, the question remains if such a system is desirable, as it probably costs a lot of time and money to implement. To collect additional information on whether the EUR should implement SAP Carbon Impact, I interviewed Marcel Hoornweg at EUR.

5.5.2 Interview Marcel Hoornweg – Erasmus University Rotterdam

At Erasmus University Rotterdam, I interviewed Marcel Hoornweg, the head of the Department SSC ICT Product Management at EUR. The reason I interviewed him was to discuss the possibilities of using advanced information systems for streamlining the carbon footprint calculation at EUR.

According to Marcel Hoornweg, the lack of management information in terms of aggregated data is a general problem. Prof. Dekker from EUR and other experts also see that this is the case for a lot of organizations. Right now, data at EUR is mainly collected for administrative purposes, according to Marcel Hoornweg. If there would be plans to gather data specifically for reporting purposes, then this should result in data of a better quality, suited for its purpose.

A problem of implementing a system like SAP Carbon Impact is that data has to be transferred to the Carbon Impact system. At this moment, data that could aid in calculating the carbon footprint is dispersed throughout the organisation. This dispersed data has to come together in one system. To do this, cooperation from people is necessary. People have to be willing to collect the data in the way you want them to.

Technical issues are not a big obstacle for implementing SAP Carbon Impact, while organizational issues are. Implementing SAP Carbon Impact would probably take a long time and cost a lot of money. The university has a limited amount of money available that should be spent in an optimal way. This means that, even if the university board would see the benefits of using such a system, there is still a good chance that it is not going to be implemented, because there are several other possible initiatives that could have more benefits for the university.

It is important that the university sees organizational benefits in using a system such as SAP Carbon Impact. The university is probably not going to use such a system solely out of idealism. Possible advantages for the university can be financial advantages on the long term (i.e. when solar panels are used), or reputational advantages. There has to be a positive return on investment on the long term.

Companies (and universities as well) often make plans for a number of years. However, investments like solar panels (which can reduce CO2 emission) can take 10 years to earn back. A payback time of 10 years can be a too long period for the university to make such an investment. This may be an obstacle for the university if they are considering using a system for calculating their carbon footprint.

An example of why technical issues are not as significant as organizational issues is the case of flight data. Data about business flights is important for calculating the carbon footprint of a university. The technical possibilities are there to integrate SAP ERP data with SAP Carbon Impact to be able to calculate the CO2 emission of flights. However, secretaries do not necessarily reserve flights in the same way every time. In order for such a system to work, secretaries have to be convinced to enter data in a standard way. To ensure quality of the data, good instructions are necessary. The finance and HR data is available, but it has to be entered in the right way. Furthermore, it is important to see what the source of the data is.

Something that could be an obstacle for using software for calculating the carbon footprint is the fact that the university is financed by the government. The reason for this is that they can provide education to students and do research. Green initiatives are not the main reason for the government to give subsidies to the university.

During the interview with Marcel Hoornweg, it became clear that technical issues are not the main obstacle towards implementing an information system for calculating the carbon footprint of the EUR. Instead of that, organizational issues seem to be an obstacle. There is limited money and time available, so the university has to prioritize on their investments. The question is whether environmental issues are a priority for the university.

In this paragraph I examined the results of the interviews that I did with two experts in the field of ICT. In the next chapter (chapter 6), I discuss this subject in further detail. Advantages and disadvantages are examined of using more advanced software for calculating the carbon footprint, as well as conditions that have to be there in order to calculate the carbon footprint in the right way.

5.6 Chapter Summary

In this chapter, the current situation of Erasmus University Rotterdam was examined. The carbon footprint of the EUR was calculated; the EUR had a carbon footprint of 14.5 million kilograms of CO2 in 2010. 78% of these emissions consist of student commuting and employee commuting. Emissions of heat and electricity aren't very high when compared to other organisations, because the EUR uses green electricity and "Stadsverwarming" (city heat). Of course there is uncertainty present in the data; an overview was given of the uncertainties of the activity for each category in this chapter. My activity has medium uncertainty on average.

The case study shows there are many improvements impossible for the activity data at the EUR. The most important ones are that data should be collected centrally in the university; the mobility survey should be done every year; travel data should be entered in the same format for all faculties, with also indicating the kilometres and mode of transportation for each travel; weight of glass, swill and confident papers should be included in the activity data and the weeks that a student or employees travelled to the university should be added to the mobility survey. ICT could also aid in collecting data that is necessary for the carbon footprint calculation. In some cases (e.g. SAP Carbon Impact), it could even aid in calculating the carbon footprint. The question is whether these improvements would be worth the effort and cost to implement at EUR. In the discussion, I will examine the case study in further detail.

6 Discussion

6.1 Chapter Introduction

In this chapter, I discuss several topics in the field of carbon footprints. Knowledge gained from the literature review, analysis and case study is taken together to form an opinion about several issues. The paragraphs and the discussed topics in this chapter are related to all the research questions that have been described in the introduction.

In paragraph 6.2, I discuss which emission categories are necessary and optional, and what data is necessary to perform CO2 calculations for each emission category. In paragraph 6.3, I focus on collecting and processing information. The calculation itself is discussed, as well as the role of information systems and uncertainty. In paragraph 6.4, allocation of CO2 emissions to research and education and between different faculties is discussed. Finally, in 6.5, I discuss if my model can be used by other organization than Erasmus University Rotterdam.

6.2 Necessary and optional data

In this paragraph I discuss what data is necessary for calculating the carbon footprint of a university. There are three basic things necessary for a calculation: activity data, emission factors and calculation rules. The first two of these are discussed in this paragraph, while calculation rules are discussed in subparagraph 6.32.

6.2.1 Emission categories

Before discussing what activity data and emission factors should be present, I first discuss which emission categories I consider mandatory or optional for universities. Categories are discussed for scope 1, scope 2 and scope 3, hence the emission categories of the Campus Carbon Calculator (CA-CP, 2010). I also discuss an additional category that I added.

For scope 1, there is actually no category at all that should be present for each and every university in the world. The Erasmus University Rotterdam proves that not every university generates its own heat and electricity. Furthermore, I believe not every university owns vehicles, so direct transportation does not have to be included for each university. Furthermore, refrigerants and chemicals do not have to be included in the calculation, because I could not find reliable emission factors specifically for CO2. This could indicate that emissions of refrigerants and chemicals are not significant. When it comes to agriculture, the lack of CO2 specific data in the Campus Carbon Calculator could suggest that agriculture emissions of CO2 are not significant. Therefore, I believe emissions of agriculture should not be included for most universities. However, in my opinion, universities that use a lot of agriculture or future researchers, should examine whether reporting CO2 emissions of agriculture would be necessary. An agriculture university such as Wageningen University may have to report CO2 emissions of agriculture. All in all, I believe that direct transportation sources and on-campus stationary sources can be important emission categories in scope 1, but universities have to decide for themselves whether emissions would be significant in these categories in their case.

For scope 2, emissions of purchased electricity and purchased heat should be reported if electricity and heat is purchased by the university. In the Campus Carbon Calculator, a distinction was made between purchased electricity, purchased chilled water and purchased steam, where the input for chilled water and steam has the same unit (MMBTU). In my model, there is only one emission category for heat. In my opinion, universities should base their choice of having only one emission category for purchased heat or having two emission categories (purchased steam and purchased chilled water) for this area on the data that is present in the university.

Scope 3 contains the most emission categories. Employee commuting and student commuting were the most significant CO2 emission categories in my calculation. Every university has students and employees that commute to the university. Therefore, employee commuting should be included in every calculation. Student commuting would be a significant emission factor for every calculation, but universities should decide for themselves whether they want to include student commuting. This should depend on their reporting goals and the extent to which they can influence emissions of student commuting. Employee travel is a category that should always be present, because every university has employees that travel for a certain reason. Every university has waste as well. If a university can make a good estimation about the waste that is disposed in a year, then this emission category should be included.

Paper should be included for each university, since universities are paper-intensive companies. Furthermore, it shouldn't be hard for universities to get data about the amount of paper that they bought. Study abroad air travel should only be included if studying abroad would be mandatory in a certain university or strongly encouraged by the university. If the student is not encouraged to study abroad by the university, then I recommend that emissions of the study abroad air travel are not included in the CO2 calculation for the university.

Wastewater should not be included when doing a pure CO2 calculation like I did, because these are sources of CH4 and N2O emissions. A category for extraction, transportation and refining of fuels should be present if these emissions are significant. For my own calculation, I chose to place these emissions under "direct transportation" and "on-campus stationary sources" in scope 1, because my emission factors included life-cycle emissions, and emissions of extraction, transportation and refining of fuels were very low compared to other emissions. However, if these emissions are significant for a university, then they should be reported separately under scope 3. Also if there are certain rules and regulations that a university must comply to, then it may be necessary to report these emissions specifically for scope 3, even if the emissions are not significant. Catering is an emission category that is not present in the Campus Carbon Calculator and the Greenhouse Gas Protocol. I also recommend not including catering in the CO2 calculation. Life cycle emission factors would have to be available for all of the sold products at the restaurant of the EUR to be able to influence the catering's CO2 emission via purchasing, which isn't the case at the moment.

Finally, I added the category "Water" in my calculation. This category was not present in the Campus Carbon Calculator. The reason for including this was mainly that data for water was easy to obtain. I believe emissions of water should usually be included in the calculations for universities, because every university uses water, and data about water usage should be easy to get.

One general comment: if a certain emission category has a significant CO2 emission, the required data is available, and a suitable calculation methodology is available, then universities should definitely include it in the calculation. If the university believes that a certain emission category is present, but only with a very low CO2 emission, then the university should decide whether they want to include the emission category. This should depend on the goal they want to achieve with their CO2 calculation and the required effort to calculate CO2 emission for that certain category. There can be a trade-off between the required time for a calculation and the benefit of including the emission category.

In this paragraph, the different emission categories that I believe should be present were discussed. In the next subparagraph, I discuss the data that is necessary for the calculations.

6.2.2 Activity data and emission factors

For calculating the carbon footprint, activity data and emission factors are necessary. Both are discussed in this paragraph. First, the necessary activity data for each category is discussed. Below you can find a table which displays the required activity data for each emission category:

Scope	Emission category	Required activity data
Scope 1		
	On-campus stationairy sources	Data about fuel use: oils, natural gas, coal, LPG, wood, etc. Data can be in terms of energy (GJ), volume (m^3 or l) or weight (kg or metric tons), depending on the emission subcategory.
	Direct transportation sources	Data about fuel use or kilometres travelled
Scope 2		
	Purchased electricity	Data about the amount of kWh consumed and the composition of the electricity mix
	Purchased heat	Data about the amount of GJ consumed and data about the source of the heat
Scope 3		
	Employee commuting	Data about the (estimated) total amount of passenger km travelled per transportation mode, possibly also data about fuel use of cars
	Student commuting	Data about the (estimated) total amount of passenger km travelled per transportation mode
	Employee travels	Data about the (estimated) total amount of passenger km travelled per transportation mode
	Water usage	Data about the volume of water consumed.
	Paper consumption	Data about the weight of the purchased paper
	Waste	Data about the weight of the waste that is consumed, preferably sorted into different categories
	Study abroad air travel (not included in my model)	Data about the total amount of passenger km travelled by airplane
	Electricity T&D losses	Data about the amount of kWh consumed (same as data for purchased electricity)

Table 11: Emission categories and the data that is required for calculating the CO2 emission of each category

In addition, emission factors are necessary for converting activity data into CO2 emission data. For example, if there is a total amount of 10000 pkm (passenger km, which means one kilometre travelled by one passenger) travelled by metro and the emission factor would be 0,100 kg CO2/pkm, then the CO2 emission of train travel would be 10000 * 0,100 = 1000 kg CO2.

The types of emission factors required can be derived from the activity data that is used. When the amount of gasoline (in terms of litres) consumed would be the used activity data, then an emission factor for kg CO2/l is used. If there is data about the amount of passenger kilometres driven by gasoline cars, then an emission factor for kg CO2/pkm would be used. The emission factors have to be tailored to the activity data. The required activity data may not always be available. For example, there may not be data present about commuting behaviour of students. In this case, an estimation can be used.

Furthermore, universities have to decide what emissions they want to account for. They should take a critical look at what the emission factors exactly mean. Some emission factors for fuels may include life-cycle emissions; others only include emissions of combustion of the fuels.

6.3 Collecting and processing information

In the previous paragraph I discussed what data was necessary for calculating the carbon footprint. In this paragraph we discuss in what way the necessary data can be collected, prepared, and how this data can be used to calculate the CO2 output of universities. Issues like allocation, uncertainty and information systems are also discussed in this paragraph, because these are all topics that (can) relate closely to calculating the carbon footprint of a university.

6.3.1 The process of collecting and preparing data

An extensive amount of data has to be collected to calculate the carbon footprint of the university. This data is often spread around different places at the university. Where the necessary data resides varies among universities. The guide for the Campus Carbon Calculator (CA-CP, 2010), and the guidelines for college-level GHG inventories by Dautremont-Smith (2002) provide explanations on where activity data can be found in the university.

My experience with the case study is that the necessary data is often not available. For example, data about flights kilometres were not available. Instead, data about flight destinations was available. For this reason, activity data often has to be prepared, meaning that pre-calculations are necessary in order to get the required activity data. For the flights this meant that online tools had to be used to calculate the distance between two cities. The way in which preparations are necessary depends on the data that is already present in the university. In the case study, a detailed description of how I collected and prepared the data can be found.

6.3.2 The calculation

The calculation itself is not a very complicated one. Deciding which emission categories to include in my analysis, finding the right emission factors and getting the necessary activity data was much more difficult. The total CO2 emission of the university can be calculated by using the following formula: $\sum_i AD_i * EF_i$. This was explained earlier in this document without this formula; the formula means that, for each subcategory, the activity data should be multiplied with the corresponding emission factor. This should be done for each subcategory, and all these multiplications should be summed up to get the total CO2 emission of the university.

My model consists of different scopes, which are divided into categories. These categories are then divided into different subcategories. For each category, my model could calculate the CO2 output. When this is done, CO2 output can be calculated for each category as a percentage of the total CO2 output. CO2 output has also been calculated per employee, per FTE, per student and per diploma. There are more possibilities for this; CO2 output could i.e. also be calculated per square meter. I recommend that universities think about how they exactly want to report their CO2 emissions.

6.3.3 Information systems

In the case study I noticed that activity data is dispersed throughout the EUR. I gathered the emission factors manually, from different sources. This was a lot of work. Using an information system could have several benefits, but also some disadvantages. In this paragraph, I examine these advantages and disadvantages, and form my own opinion on whether universities should use information systems for their carbon footprint calculations.

During the interview with SAP, it became clear to me that using an information system for calculating a carbon footprint could have many benefits, compared to using an Excel sheet for calculations. First, it could enable central collection of the data specifically for the purpose of calculating the carbon footprint. At this moment, environmental information is spread throughout the organization. Using an information system could motivate a university to collect data in a centralised and planned way. This would greatly reduce the time that is necessary to calculate the carbon footprint. Also, collecting data in a planned way may reduce errors in the data. A second, related benefit is that connections between databases are possible. For example SAP Carbon Impact can be connected to other databases of SAP, to retrieve activity data from these databases. There is also an interface for inserting Excel sheets for use in the calculations. Third, SAP Carbon Impact provides a sophisticated way of reporting the CO2 emissions, including clear diagrams. Fourth, it can enable the calculation of the CO2 footprint in a standardized way (although this can also be done with a spreadsheet like the Campus Carbon Calculator).

Despite these benefits, the question remains whether universities should use SAP Carbon Impact or another information system that can aid in calculating the carbon footprint. There are several obstacles towards implementing such information systems. These obstacles are mostly organizational obstacles, rather than technical obstacles. First, the university has to pay for the information system. The minimum costs for using SAP are 22500 euro per year. This includes administration, support, new releases, content upgrades and 60 hours of support for implementing the system. Second, the university has to convince their employees to gather and administer data in a standard way, to make sure that the data can be used with the information system that is present. Many changes in the way data is collected are necessary for this. People need to get used to a different way of working, which can take time and effort (so also money). Third, even if most people get used to the new way of working, some people may still make mistakes and provide data that is not suitable to use in the CO2 calculations. Effort may have to be done to make it difficult for people to make mistakes when they are delivering data to the university. Fourth, using a system like SAP Carbon Impact may decrease the flexibility of universities, compared to the way the carbon footprint was calculated by using my own model. Fifth, universities may have higher priorities. Even if they have a positive attitude towards using an information system for these calculations, they have limited money available to make investments.

There are advantages as well as disadvantages towards using a system like SAP Carbon Impact for calculating the carbon footprint. For calculating the carbon footprint, I think using an information system could be a good solution. I believe that, for most universities, using a system like SAP Carbon Impact would be an improvement to the way they are currently calculating the carbon footprint, if they calculate the carbon footprint at all. An information system has the potential to greatly reduce the effort in calculating the carbon footprint, and it enables the carbon footprint calculation to be done in a standard way. However, this does not mean that I recommend using a system like SAP Carbon Impact for all of these universities. This depends on several things.

I recommend that universities take a few steps to decide if they want to have a special information system for calculating the carbon footprint or if they want to use a simple spreadsheet like my model or the Campus Carbon Calculator (CA-CP, 2010) for their CO2 calculation. There are a few questions that the university should answer for themselves:

- Why am I calculating the carbon footprint?
- What improvements could the information system have to the way in which I currently calculate the carbon footprint?
- Could there be a way to improve our way of calculating carbon footprints without implementing an information system for it?
- Can our employees deliver us the data that we need for the calculation, in the format in which we need it?
- Are the benefits of the investment worth the costs?
- Is there enough budget available to cover the costs?
- Are there other investments possibilities with a higher priority?

The answers to these questions should help universities in deciding whether having an information system for calculating the carbon footprint would be desirable, possible and worth the investment.

For the EUR, there are several answers to these questions that I do not know myself. I do not know whether the university has sufficient budget to buy a system like SAP Carbon Impact, and what the priorities of the university are when it comes to making investments. I do not know whether the benefits of SAP Carbon Impact would exceed the costs.

When I look at the issue from my own point of view, I think that using a system like SAP Carbon Impact would definitely be good to have for the university. I had to put much effort into calculating the carbon footprint of the university. Using Carbon Impact can enable the carbon footprint to be calculated in a more efficient and standardized way. However, if the university wants to use SAP Carbon Impact, someone at the university has to take the responsibility to calculate the carbon footprint. Furthermore, the IT department of the university has to make the effort to create the database connections that can partly automate the data collection. In addition, employees have to be motivated to deliver data that is not part of the ERP system of the university in the way that is required for the calculation. If these conditions are satisfied, then I definitely think having an information system for calculating the carbon footprint would be a great improvement for the Erasmus University Rotterdam.

One of the problems at Erasmus University was collecting the activity data. Before my calculation sheet could be used, lots of pre-calculations had to be done to get the necessary data for the calculations. For this reasons, I recommend that universities invest in simple programs that process the collect and process data in an organization to get the required activity data for the calculations. Regardless of the calculation method that is used, such programs could automatically provide activity data for the calculation.

6.3.4 Uncertainty

A lot of uncertainty is involved in the calculations. Activity data is often subjective and the result of pre-calculations. Emission factors are usually average emissions per unit for certain processes. The situation at the Erasmus University Rotterdam is of course not a completely average situation. Therefore, the total CO2 emission that was calculated is not equal to the actual CO2 emission of the university. However, we could try to minimize the uncertainty of the calculations by trying to verify that the CO2 calculation estimates the actual CO2 emission in a correct way. I believe there are multiple ways in which this can be done:

- The simplest way: check your calculations and your data to see if everything is correct.
- Comparing your own calculation to someone else's calculation. When I first calculated the CO2 footprint of EUR, the calculated CO2 emission of waste was about 15% of the total calculated CO2 emission of the university. When I compared this number to reports of other universities, it turned out that this percentage was very high. When I looked back at my calculation, I came to the conclusion that I made a mistake in my calculation.
- Be transparent about your calculations. In my spreadsheet, almost all of the data that I have is visible. No calculations that are done in the spreadsheet are hidden.
- Something related: keep all source files. If you have all your data available, then it is always possible to check the source of the data for verification
- Sensitivity analysis

Verification can also be done by a certification body or another third party. These people may see things that the person that did the initial calculation did not see. Sensitivity analysis is a more specific process that I thought deserved a little more attention. With sensitivity analysis, the influence of specific alternative scenario's on the CO2 calculation is examined. This is what I did in the case study for several scenarios. When sensitivity analysis is done, this gives information about the robustness of your data. If the calculation turns out to be not robust enough, then changes may have to be done. For example, in the case study at EUR, the way in which commuting distances for each transportation mode were calculated had some influence on the total CO_2 emission of the university, even though it was less than 1%. In the case of EUR, better quality data for commuting gives more certainty to the calculation.

The uncertainty of the calculation greatly depends on the data that is present in the organisation. For example, the Erasmus University Rotterdam could easily have measured the kilometres travelled by their company cars in 2010, by subtracting the odometer's distances at 31 December 2010 by the odometer's distances at 31 December 2009. This would have resulted in a very reliable estimation of the travelling distance by direct transportation. Same is true for waste: it is not that hard to figure out what the weight of a filled container is. This would have resulted in a waste calculation that is way more reliable. Not only would these improvements lead to an improved CO_2-calculation, but would also improve the management information in general, which can be used for many other management decisions and would result in a more effective and efficient organisation.

6.4 Allocation of emissions

In this chapter I already discussed the way in which the CO_2 emissions for different categories and for the university as a whole can be calculated. However, I did not speak yet about allocation within different parts of the university. In my model, I allocated emissions to research and education. This is the first topic I discuss in this paragraph. The second topic is allocation to different faculties within the university. This was something that I initially wanted to do, but it turned out to be too difficult and time-consuming to do this.

6.4.1 Allocation of emissions to research and education

In the model that I used for the case study, I allocated emissions of research and education by using a rule that allocated 60% of the emissions to research and 40% of the emissions to education when allocation was necessary. Allocation was necessary for all categories, except student commuting (where the entire emission was distributed to education) and employee travel (where the entire emission was distributed to research). In this subparagraph I discuss which other methods would have been possible for allocation of emissions between research and education.

For scope 1, there are two different emission categories present in my model: on-campus stationary sources and direct transportation sources. Although my model did not include it because the EUR does not generate heat and power, co-generation of heat and electricity is also a part of on-campus stationary sources.

For direct transportation, allocating the emissions using the 60 – 40 key (or a similar key, depending on the time employees spend on research and education in a university) is the best way. Vehicles are not owned by any of the faculties and emissions of the vehicles are therefore difficult to allocate to education or research.

For on-campus stationary sources, there are other allocation methods possible. Different allocation methods may be present for on-campus stationary sources, depending on the subcategory. For the subcategory "other on-campus stationary sources", I believe the 60 - 40 key is sufficient, because it is a collection of the combustion of fuels that does not belong to co-generation of heat and electricity; therefore this subcategory can include emissions from different sources. Because these sources may differ much among universities, I believe the 60 – 40 rule is sufficient.

For co-generation of electricity (scope 1), co-generation of heat (scope 1), purchased heat (scope 2) and purchased electricity (scope 2), a different key may be used than the 60 – 40 rule. I call this rule the **area key**. I believe the area that is occupied by research and education could decide how much of these emissions could be allocated to each discipline. The area of the spaces that research and education use is probably one of the best estimators for the extent of electricity and heat used. The university then has to find a way to find the total amount of square metres of research and education. For some areas, like lecture halls (education), it is clear where the space is used for. However, for some areas it is not. Therefore, some allocation key would be necessary for the areas. Areas of office space could be allocated to research space and education space by using the 60 – 40 rule. Corridors and restaurants could use a similar key, but I would think 30 % to research space and 70% to education space (30 – 70) would be a better allocation key than 60 – 40, because I believe corridors and restaurants are mostly used by students.

If a calculation is done to define the amount of space allocated to research and to education, then this can serve as the basis for the allocation key for electricity and heat. For example, if 2000 m^2 would be research space and 1500 m^2 would be education space, then 4 / 7 of the emissions of (co-generated and purchased) heat and electricity should be allocated to research, and the rest to education. However, such a calculation costs some effort. A substantial amount of data has to be gathered about the different rooms in the university and where these rooms are used for. If the people at a certain university are ready to put some effort into such a calculation, then I believe this is a better way of allocating emissions than the 60 – 40 rule.

Even if using such a complicated rule is not possible, then an advanced, but less complicated rule may be possible for heating and electricity. An example is to use the average amount of students and employees that are in the building at a given time. I call this the **time key**. If 3000 employees spend an average of 4 days a week at the university for 8 hours a day, then these are 1000 * 4 * 8 = 32000 employee hours a week. If the 5000 students at the university spend an average of 3 days a week at the university, for an average of 5 hours, then this is 50000 * 3 * 5 = 75000 student hours a week. Student hours can be fully assigned to education, while employee hours can be allocated partly to research (i.e. 60%) and partly to education (i.e. 40%). We can then get an allocation key for research of 0,6 * 32000 / (32000+75000) * 100% = 17,9%. This is significantly different than the 60% of the 60 – 40 rule. Of course this is no true data that was used, but I still believe that such an allocation key for electricity and heat would be more accurate than the 60 – 40 rule. On the other hand, I believe it is less accurate than the rule that allocates emissions by using areas used for research and education, the area key. The reason for this is that I believe that students often come to the university for lectures. A lot of students are then present in a relatively small area. If emissions are allocated by the amount of research and education hours, then too many emissions may be allocated to education for this reason.

Another possibility would be to use a rule that combines the time key and the area key. This rule would probably be quite accurate, but this would require more effort than using one of these individual keys. Universities should decide for themselves what rule they prefer, based on the time/resources available and the desired accuracy.

Allocating scope 1 and 2 emissions has been discussed now; scope 3 emissions still have to be discussed. Not all scope 3 emissions have to be allocated; I recommend that 100% of the student commuting emissions are assigned to education and I recommend that 100% of the emissions of employee travel are assigned to research.

A number of other categories are then left for scope 3. Emissions of employee commuting should be allocated by using the 60 – 40 rule; I think time spent on research and education is a good way of allocating emissions of commuting. For waste and water, I believe the time key that is explained earlier in this subparagraph is a good method of allocation, because I think that water use and the amount of waste disposal of a person can be expressed by a function of the time that someone is present at the university. For paper consumption, I think the time key could also be a good option, although employees use more paper than students. Therefore, too many emissions may be allocated to education if the time key is used. I therefore think the 60 – 40 rule would also be a fine rule to use for allocating emissions of paper. A combination of both rules may be even more realistic. Finally, the same rules that are useful for co-generated and purchased electricity apply to electricity T&D losses.

One more situation that I would like to discuss is when the choice is made to use a simple (% research - % education) rule for allocation of heating, waste and water emissions. If advanced rules are not possible, then I believe emissions of heating, waste and water should use an emission factor that is slightly more directed towards education than the rule that allocated emissions based on time spent on research and education of employees, because of the large amount of students that emit waste, use water and use heating; for students, emissions should be allocated to education. Perhaps a similar simple rule could be used, but one that allocates more to education compared to the previously mentioned rule.

For some other universities, 60% research and 40% education may not be the best approximation of time spent by employees on research and education. Every university should decide for themselves which allocation key to use. Therefore, when I talk about the 60 – 40 rule in this chapter, then I generally mean that this is the rule I used for allocating time of employees spent on research and education. So the allocation does not necessarily have to be 60 – 40, but it could also be 50 – 50.

In this paragraph, I explained what other rules may be used for allocating emissions. The time key and the area key are examples of other rules that could be more accurate in some situations. In addition, if a simple rule is used, like the one that allocates emissions based on time spent on research and education by employees, then the percentages may have to be altered for some emission categories. Based on the accuracy that a university desires and the time and resources that the university wants to spend, universities should make choices on the allocation rules they want to use (if they want to allocate emissions between research and education).

6.4.2 Allocation of emissions to different faculties

In the previous subparagraph, allocating emission between research and education has been discussed. This subparagraph focuses on allocating emissions to different faculties within the university. In my case study, I chose not to allocate emissions to different faculties. The reason for this is that there was not much data that would allow me to allocate emissions to different faculties. Furthermore, most faculties are obliged to follow university-wide policies and only have limited influence on the CO2 footprint with their own policies. However, if the data is present, then CO2 emissions could be allocated to different faculties, because faculties can still influence their CO2 to some extent. In this paragraph I examine the possibilities for this. Often, similar rules can be used as the ones that were explained in 6.4.1.

For allocating emissions of direct transportation sources, the amount of FTE of each faculty could be used as an allocation key. This is a simple key that would not enable the faculty policy to influence the calculated CO2 emission of their faculty.

For electricity and heating, the best allocation key is more advanced and could only be used if data is available about the amount of consumed heat and electricity for each building. Emissions can be calculated per building, based on the consumed heat and electricity per building. However, sometimes a building can be used by multiple faculties. Estimations should then be done of the percentage of space that each faculty uses in a certain building, to define how much of the emissions of a building should be allocated to a certain faculty. I call this allocation key the **faculty – building key**. Gathering data about the area used per faculty in a certain building may be hard. Some parts of buildings will be used by the university as a whole and not by (a) certain facult(y)(ies). Emissions of such parts of the building should then be allocated by using a general allocation key, such as the amount of FTE.

An alternative method could be to allocate emissions based on the number of students and employees of each faculty; this is what I call the **student – employee key**. It should be easy to get data about the number of students and employees of each faculty. A possible way to do this is computing the amount of students + 2 * amount of employees for each faculty, and use this as a method of allocation (because employees are likely to spend more time at the university). However, just as with using FTE an allocation method, it is a simple key that would not enable the faculty policy to influence the calculated CO2 emission of their faculty. The next key has this same characteristic, but is a little bit more advanced.

A similar allocation key would be to use a rule similar to the **time key** expressed in subparagraph 6.4.1: emissions could be allocated to a certain faculty, based on the sum of the estimated time spent in the university by employees and students of each faculty. I call this rule the **faculty time key**. I am indifferent between the two allocation keys that are explained in this paragraph and the last paragraph. The faculty time key is slightly more accurate, while the student-employee key is easier to use.

Scope 3 is the last emission category to be discussed. Emissions of student commuting can be allocated by using the amount of students per faculty. Emissions of employee commuting can be allocated by using the amount of FTE per faculty. For some universities, activity of employee commuting may be available per faculty. In that case, allocation is not necessary at all. Employee travel could be allocated by using the amount of FTE, but allocation is not even necessary when universities already collect travelling information per faculty which allows to directly assign the CO2 to the different faculties.

What I said about emissions of heat and electricity also counts for emissions of waste, water and paper: they could all be allocated by using the faculty-building key, the student – employee key or the faculty time key. Again, there is a trade-off here between accuracy of the data and ease of calculation. At EUR, paper consumption is already readily available per faculty, which allows direct assignment of CO2 per faculty.

In this paragraph, some other allocation keys have been introduced; allocation keys that are specific for allocating emissions between different faculties within a university. Just as with allocation of emissions between research and education, there is always a trade-off between the accuracy of the allocation key and the required effort and difficulty of collecting the data. Universities have to decide carefully whether they want to allocate emissions between faculties, and how they want to allocate it if they choose to allocate emission to different faculties.

6.5 Differences between different types of organizations

In the case study, I created a model for the calculation of CO2 emissions of universities. I believe my model can be really useful for some universities that want to calculate their CO2 emission. In this paragraph, I describe how my model could be used by other universities.

People who know the GHG protocol (WBCSD & WRI, 2003) and the Campus Carbon Calculator (CA-CP, 2010) can probably recognize the influence these tools had on my model. However, some ideas of my own were incorporated into my own model. Furthermore, the model is specifically tailored to EUR.

The emission categories that are present, represent the most important emission categories of universities. Most of the emission categories that I use are present at every university. There are some exceptions. For example, there are probably universities that do not own any vehicle; direct transportation in scope 1 is therefore not a present emission category at their university. If such a university would want to use my model, then they could simply fill in 0 for all the activity data that is present in the category “direct transportation”.

Some universities may have emission categories that are not present in the model. These universities could extend my model to incorporate these emission categories. They can use the Campus Carbon Calculator for inspiration on which subcategories to include and which emission factors to use. Emission factors could also be retrieved from other sources. In addition, there are certain emission subcategories that are not present in my model. For example, LPG is not included as a possible fuel in my model. Instead of that, there is a category “other” for all car fuels that are not specifically present in my model. If a university would have cars that drive on LPG, then they could consider adding the LPG subcategory for direct transportation and/or employee commuting.

Universities that have significant scope 1 emissions should adjust my model a little bit. For one item, my model does not comply with the GHG protocol (WBCSD & WRI, 2003) when it comes to the scopes. My model incorporates life cycle emissions in scope 1, because these emissions are only a tiny part of the total CO2 calculation for EUR. Having a separate emission category in scope 3 for extracting, refining and transporting fuels was not my preference, because it would not improve readability and understandability of my results table. However, if emissions of extracting, refining and transporting used fuels for direct transportation and on-campus stationary sources scope are significant, then these emissions should be reported separately, and the emission factors that I provided for scope 1 should not be used.

Another characteristic of my model is that it incorporates pre-calculations that were necessary for getting the necessary activity data. These pre-calculations were tailored to the present data at EUR to aggregate and/or transform activity data for some of the emission categories, to create the activity data that was necessary in the main calculation sheet of my model. These pre-calculations are mostly not usable for other universities, because they are directly tied to the present data of the EUR. However, these pre-calculations are only there, because the data of the EUR is not perfect. If a university would keep track of their activity data perfectly, then no pre-calculations are necessary at all. If the activity data of another university is imperfect, but different than the activity data of the EUR, then this university has to do their own pre-calculations to be able to enter activity data into the main calculation sheet of my model.

All in all, I believe my model can easily be used by other universities that want to calculate their CO2 footprint. However, they should take into account the things that were described in this paragraph.

6.6 Chapter Summary

In chapters 4 and 5, a model was proposed for calculating the carbon footprint of the Erasmus University Rotterdam. In this chapter I examined to what extent the model could be generalised to other universities. Furthermore, I discussed some topics in the field of calculating carbon footprints in detail. Several conclusions can be drawn from this discussion. These conclusions can be read in the next chapter.

7 Conclusions and recommendations

7.1 Chapter Introduction

In this chapter, the conclusions of this research are summarized. First I would like to motivate why I chose only to incorporate CO_2 emissions, as this is not part of any of the sub questions. There are two main reasons. First, less research has been done about CO_2 emissions in particular, so my thesis can be a valuable addition to the knowledge base. Second, focusing on CO_2 was necessary to limit the scope. In addition, in paragraph 4.3 we showed that focusing on CO_2 emissions only still gives a reliable representation of the GHG emissions that were released into the air. However, I do not want to say that reporting CO_2 emissions instead of CO_2e is necessarily better. There is also a disadvantage; reporting CO_2 emissions only can give a less incomplete image of the environmental damage for emission categories that have significant NO_2 or CH_4 emissions as well, like emissions of waste and paper.

In paragraph 7.2, my answer to each sub question is given. The answers to these sub questions are taken together to answer the main research question in paragraph 7.3. In paragraph 7.4, I present my specific recommendations to Erasmus University Rotterdam regarding the calculation of the carbon footprint. Paragraph 7.5 present a short overview of the lessons that I learned when writing my thesis and doing my research. In paragraph 7.6, possible directions for future research are discussed.

7.2 Conclusions of sub questions

7.2.1 Sub question 1: How much detail should be included in CO2 administrations?

This sub question is about the emission categories that should be included in the calculation. My first recommendation is that universities should decide for themselves what emissions they want to report on and how they report it. This depends on the data that is available, on the goal of the calculation and on the required effort for doing a certain calculation. There are a few emission categories that should definitely be present in every calculation, because these emission sources are present for every university:

- Employee commuting
- Employee travel
- Heat (either purchased or self-generated).
- Electricity (either purchased or self-generated)
- Purchased paper

Employee commuting and employee travel are included in scope 3. Heat and electricity should be present in scope 1 or scope 2 (or both), and possibly also in scope 3. In which scopes emissions should be reported depends on how the emission is generated. If the university itself combusts fuels for generating heat or electricity, then scope 1 emissions should be reported (in my model it would be reported under “on-campus stationary sources”). If the university buys electricity or heat, then these emissions should be reported in scope 2. If the university wants to include life-cycle emissions of the extraction, refining and transportation of fuels, then I recommend reporting it in scope 3 if these emissions are significant. Emissions of purchased paper should be included in scope 3.

Student commuting, the biggest emission category for Erasmus University Rotterdam, is not included in the list above, as universities have to decide for themselves whether they believe including student commuting is relevant for the purpose of their calculation. There are a number of emission categories that I strongly recommend universities to include in their calculation, but I believe there can be valid reasons for excluding one or more of these categories:

- Scope 3: student commuting
- Scope 3: waste
- Scope 3: water
- Scope 3: electricity T&D losses

In addition, there are some emission categories that I recommend to include, but only if these emissions are significant for a certain university. Each university has to decide for themselves whether to include them in their calculation:

- Scope 1: other on-campus stationary sources (on-campus stationary sources that are not used for producing heat or electricity)
- Scope 1: direct transportation (by vehicles owned by the university)
- Study abroad air travel (if the university encourages studying abroad)

For a number of categories, I recommend that they are not included in the calculation. These categories are commonly included in GHG emissions calculations (in terms of CO2 equivalents), but I believe these emissions are not significant for CO2 in specific:

- Refrigerants and chemicals
- Wastewater
- Agriculture (with the exception of agriculture universities)

I recommend not including catering in the calculations. Emissions or catering are not included in the Campus Carbon Calculator, not all the required emission factors are available and people would also consume food and drinks at home as well. For Erasmus University Rotterdam in specific, I recommend including all of the emission categories that I mentioned in this paragraph, except for refrigerants and chemicals, wastewater, agriculture, catering and study abroad air travel. Student commuting, employee commuting and employee travel are the emission categories that require the most pre-calculations, but there are significant CO2 emissions for all of these categories. Therefore, these emission categories should be included. For the other emission categories, not many pre-calculations are necessary. Therefore, it does not require much effort to include these categories in the calculation. However, there are some categories that I consider to be the least important to include for EUR: direct transportation (0,01% of the total CO2 emission), on-campus stationary sources (0,11%) and waste (0,86%, lots of uncertainty and some uncertain pre-calculations are necessary). If the EUR would calculate their CO2 emissions in the future, then it would be understandable if they would exclude these categories. However, for the sake of completeness, I recommend to include them. Currently, the EUR is rebuilding on their campus. Emissions of rebuilding are significant and may be incorporated in the carbon footprint in the future, by incorporating emissions of the contractors. However, at this moment, the available methodologies and data are not sufficient to make such a calculation.

7.2.2 Sub question 2: How should information be gathered, processed and presented?

The data that has to be gathered is directly related to the different emission categories that are included in a calculation. Activity data and emission factors have to be collected in order to do the calculation. In subparagraph 6.2.2, a table can be found with the necessary activity data for each emission category. Emission factors should be tailored to the activity data that is present in the organization. Furthermore, I recommend that emission factors are used that include as many emissions in the life-cycle as possible.

The way the data is gathered depends on the organization. It is possible to use IT to make a connection between databases to automatically connect the data. However, more often, universities will have to contact many people in the organization to receive all the required activity data for the calculation. Furthermore, the required activity data may not be present in the organization. Therefore, sometimes estimations have to be used. In order to get to these estimations, some pre-calculations have to be done.

For the Erasmus University Rotterdam, pre-calculations were necessary for the emission categories student commuting, employee commuting, employee travel, direct transportation, waste and paper. This was quite a lot of work. I recommend that the EUR keeps track of the weight of the paper bought in the copy shop, the distance travelled by their owned cars, the weight of all their waste types and the amount of kilometres travelled to foreign countries by their employees. This would greatly reduce the time that is necessary to prepare the data.

When the data is gathered, the calculation has to be done. The calculation itself is not a very complicated one. The activity data for each (sub)category is multiplied by its corresponding emission factor, all the multiplications are summed up to get the total CO2 output of the university. For reporting purposes, I recommend that emissions are reported per emission category, while the emission categories are divided into scope 1, scope 2 and scope 3. CO2 emissions can be reported in kg CO2 or (when reporting for a certain category) as a percentage of the total CO2 emission. CO2 emission can also be expressed per employee, per student, per diploma or per FTE.

The CO2 emission can be calculated by using a simple tool like Excel (as I did in my own model), or by using a more advanced information system. It is possible to use information systems to assist in gathering the data, doing the calculation and presenting the results. Using an information system can significantly reduce the effort that is required to collect the data. Furthermore, it can result in a standard way of calculating the CO2 emission and a sophisticated presentation of the results. However, using such an information system costs money and time to implement, people have to get used to a different way of working and universities may have different priorities for making environmental investments. All in all, using an information system should be better than using a simple Excel sheet, but there are some obstacles as well. Therefore, I do not want to say that every university should use an information system for calculating the carbon footprint. Instead of that I recommend that every university critically thinks about the pro's and cons of using an information system for calculating the carbon footprint. If the Erasmus University Rotterdam is willing to invest enough time in correctly implementing an information system like SAP Carbon Impact, then I definitely recommend using it from not only an environmental point of view, but also from a financial and reputational point of view. However, the EUR has to decide whether such an investment is worth their money and time.

If a university chooses not to make an investment in an information system, then a choice for a different calculation method has to be made. For Erasmus University Rotterdam, I recommend to use my model if they want to do a CO2-specific calculation, because my model is tailored to EUR. However, if the EUR prefers a method that is often used by other universities (i.e. for comparability or proven effectiveness), then they could use the Campus Carbon Calculator. More on the way in which other universities can use my model can be found in my answer to the last sub question.

Universities should also invest in simple programs collecting and processing the data. For example, the mobility survey could directly calculate the distances for each travelling method. Regardless of the calculation method that is used, such programs could automatically provide activity data for the calculation.

There is always uncertainty present in the calculation. It is possible to try to assess the correctness and uncertainty of the calculation. There are multiple ways to do this. First, it is possible to simply scan the data to see if everything is correct. Second, a comparison can be made with another university's calculations, to see if there are any huge, unrealistic differences. Third, uncertainty can be less when source data is being kept in a structured way, to be able to check the source of the data for verification. Fourth, sensitivity analysis is possible. With sensitivity analysis, we can examine the influence of specific scenario's on the CO2 calculation. Certain emission categories can be removed, or the method of calculation can be changed to check what the influence of this would be on the CO2 calculation. This gives information on the robustness of the data. For this reason, a sensitivity analysis was done at EUR. The uncertainty of the data differed among the different emission categories. The degree of uncertainty is dependent on the data that is present in the organization.

7.2.3 Sub question 3: How can emissions be allocated to the various objects that cause CO2 emissions?

There are two basic ways in which I have answered this question: I assessed how emissions can be allocated to different outputs of the university and between different faculties within a university. First I want to make a general comment: if a university wants to allocate emissions within the university, then I suggest using different allocation methods for different emission categories, because of the nature of certain emissions. Second, in this paragraph I sometimes refer to certain allocation keys. These allocation keys have been described in more detail in paragraph 6.4.

The two most important outputs of the university are education and research. I discovered that it is hard to allocate emissions to research and education. Although there are certain methods for it, allocation methods are often arbitrary and cannot exactly allocate emissions in the right way. However, these methods can estimate the CO2 emissions of research and allocation.

For allocation of emissions to research and education, I have found a number of allocation keys to do this:

- Key that allocates emission based on the percentage of time that is allocated to research and education for employees' work, called the **60-40 key** if 60% is allocated to research and 40% to education (can be used for each emission category, except for student commuting and employee travel)
- Key based on the estimated area that is used by research and education, the **area key** (only for emissions of heat and electricity). Best allocation key for heat and electricity.
- Key based on the estimated time that students and employees spend in the university, the **time key** (only for heat, electricity, waste, water and paper). The most accurate key for waste, water and paper.

Similar keys are present for allocation between different faculties within a university:

- Key that allocates emissions of the university to different faculties based on the FTE that each faculty uses, the **FTE key** (only for direct transportation sources, employee commuting and employee travel)
- Allocation by using the amount of students per faculty (only for student commuting)
- Key that allocates emissions to different faculties based on the part of the area of a certain building that a faculty uses, the **faculty-building key** (Only for heat, electricity, waste, water and paper. Best allocation key for these emission categories).
- Key that allocates emissions to different faculties based on the amount of students and employees of each faculty, **student – employee key** (only for heat, electricity, waste, water and paper)
- Key that allocates emissions to different faculties based on the sum of the estimated time spent in the university by students and employees of each faculty, the **faculty time** key. This key is very similar to the time key that was defined for allocating emissions between research and education (only for heat, electricity, waste, water and paper)

For different emission categories, different keys may be used. For example, to allocate heat or electricity to research and education, the area key can be suitable. However, the area key is not suitable for allocating emissions of employee commuting, because there is no connection between the area used for research and education and the CO_2 that is emitted by employees that are commuting. Furthermore, there is often a trade-off between the effort that is required to use a certain allocation key and the accuracy of a certain allocation key. Using the area key costs a lot of effort, because an estimation has to be made of the occupied area by research and education. Therefore, universities have to make a choice on whether to use a more accurate allocation key, or an allocation key that is easier to use. Universities should take the effort that is required to use a certain allocation key into account when deciding which key to use. For some universities, data may be easier to collect than for other universities.

In addition, universities have to decide if they want to allocate emissions within the university at all. Often, the allocation mechanisms are arbitrary. For example, if you allocate emissions by using the FTE key, then emissions are allocated between faculties based on the amount of FTE of each faculty. However, with this key, policy of the faculty to reduce their own emissions may hardly be visible in the carbon footprint of a certain faculty, because emissions of the university are allocated based on FTE, and faculties will and should not lower their FTE just for the sake of CO2 reduction. Allocation between different faculties should only be done if a faculty can create its own policy of reducing CO2 emissions to a certain extent. It would not be useful to allocate emissions between different faculties if the university board makes all the decisions.

For EUR, my opinion is that allocating CO2 emissions to different faculties is not worth the effort. There are two reasons for this. First, it is hard to accurately allocate emissions to different faculties within the university. The required data is not yet available for this. For employee commuting, student commuting and waste (76% of total EUR emission), the data of the EUR is only available over the whole university. Faculty policy cannot influence the CO2 measurements of their own faculty in specific here. Second, the university makes most of the decisions that could influence the carbon footprint on a higher level. Although the faculty has some minor influence (i.e. for paper and employee travel), for the most important emission categories (student commuting, employee commuting, purchased heat and purchased electricity), university policy has by far the biggest influence.

However, allocating emissions to research and education is more useful to the EUR. This allows emissions to be reported in many different ways. For example, CO2 emissions can be calculated per diploma, per scientific publication and per student/year. Furthermore, this allocation method is more accurate than allocating emissions between different faculties at the EUR. The university should decide themselves which allocation keys they should use. There is a trade-off between the required effort to use an allocation key and the accuracy of the key.

7.2.4 Sub question 4: How can differences between different organizations be incorporated into the model?

The model that I created for calculating the CO2 footprint of a university can be used by other universities as well. The emission categories that are present in my model are the emission categories that are often used by universities. However, my model includes emission categories that are not present at some universities. In addition, there are also emission categories that are present at other universities, but not in my model. The same is true for possible emission subcategories (like emissions of LPG fuels used for cars) that are not present in my model. Furthermore, emissions of extracting, refining and transporting fuels are included in scope 1 in my model, but it would be better to include them in scope 3 if these emissions would be significant for a certain university.

Another possible change is that emission factors can be added if new emission categories are added. In addition, some emission factors have to be changed if a different university would want to use my model. Emission factors for purchased electricity, purchased heat and waste should probably all be changed if a different university wants to use my model. The reason for this is that the emission factors that are used for these emission categories are specific to the Erasmus University Rotterdam. The emission factors for heat and waste are collected at the companies that deliver the heat and process the waste. Furthermore, the emission factor of the specific electricity mix of the EUR was calculated by me. Because of the specificity of my emission factors, other universities would probably get a more accurate calculation if they changed the emission factors for electricity, heat and waste. The emission factors for the other emission categories are more general and do not necessarily have to be changed. In addition to the issues that I stated before, a different university may have to do some pre-calculations to make their activity suitable for my model. Some pre-calculations were present in my model to aggregate and transform activity data of the EUR to be able to enter it in the main calculation sheet, but other universities will have to do their own pre-calculations if their data has a different format than the data at the EUR.

All in all, my model would be usable for many universities, but some adjustments may be needed to make the model align with the characteristics of a certain university. Some emission categories may be added or removed, and emission factors may be changed. In addition, another university may need to do some pre-calculations to get the activity data that is necessary to use my model.

7.3 Conclusion to main research question

My main research question was:
How should Erasmus University Rotterdam and other universities calculate their carbon footprint?

First, the university should decide what they exactly want to calculate. A decision has to be made on what emission categories should be included in the calculation. Employee travel, employee commuting, heat and electricity are categories that should be included for every university. I strongly recommend including student commuting, waste, water and electricity T&D losses, but there may be valid reasons to exclude 1 or more of these categories. The categories direct transportation, paper, and other on-campus stationary sources (on-campus stationary sources that are not used for producing heat or electricity) are less important to include, but I recommend including these categories nonetheless. For the Erasmus University Rotterdam I recommend to include all of these emission categories, although I consider direct transportation, on-campus stationary sources and waste to be less important.

After deciding what emission categories to include, data has to be gathered that is directly related to the different emission categories. Emission categories are grouped into scope 1, 2 and 3. Gathering data may be done automatically by using IT, or by gathering the data manually from different parts of the organization. For each category, activity data and one or more emission factors are necessary. I recommend using emission factors that include as many emissions in the life-cycle as possible. Pre-calculations may be necessary to get the desired activity data. This is especially the case for EUR, where the desired activity data was not present for some emission categories.

The CO2 emission of an emission category is calculated by taking the sum of the multiplications of the activity data with the emission factors. The total CO2 emission can be calculated by summing up the emissions of the different categories. There is always uncertainty in the calculation. The uncertainty in the calculation depends on the quality of the data of the university. The degree of uncertainty can be assessed by doing a sensitivity analysis. Certain formulas or values can be changed to check what the impact is on the calculation. The uncertainty of the calculation depends on the present data in the organization. At EUR, the uncertainty was estimated per emission category. The “waste” category had the highest degree of uncertainty for EUR.

Advanced information systems such as SAP Carbon Impact may be used for calculation of the carbon footprint. This could have several benefits, like reduction of the required effort of doing a CO2 calculation and standardization of the calculation. However, universities should weigh the benefits against the costs and effort that is necessary to implement the information system and against other priorities that the university may have. From an environmental perspective, I recommend that the Erasmus University Rotterdam should use an advanced information system like SAP Carbon Impact, for calculating the carbon footprint. However, the university should only do it if they believe it is worth the money and the time. In addition, they should take the effort to implement it properly.

Universities that calculate their carbon footprint have to decide whether they want to allocate their emissions between the different outputs (research and education), and between faculties. Allocation of emissions between different faculties should only be done if the faculty has the possibility to control (a part of their) CO2 emissions. Different allocation keys are possible for different emission categories. If they decide to allocate CO2 emissions within the university, then the university has to decide what allocation keys are going to be used. This should be decided based on the required effort to use a key, and the accuracy of using a certain allocation key. For the Erasmus University Rotterdam I recommend including allocation between research and education and excluding allocation among different faculties in the calculation.

The model that I created for calculating the carbon footprint of the EUR can be used for calculating the carbon footprint of other universities, but some adjustments may be necessary. Emission categories may be added or removed, emission factors may be changed and some pre-calculations may be necessary before being able to use my model.

7.4 Lessons Learned

There are a lot of lessons that I learned from doing this research. First, I gained much knowledge on the topic of carbon footprints. Second, my supervisor has taught me a different way of doing research than I have done before. For my bachelor thesis and seminars I always answered my research question by doing a literature review and interviews only; this was quite a different approach. Third, I learned that, for some tasks, I was quite dependant on other people. That taught me that it is important to start early with your tasks, because you may have to wait a long time before getting a certain response from certain people. Finally, I learnt that data is often spread across an entire organization. This research taught me how to collect data from the entire organization, do calculations with the data, and interpret the data.

7.5 Research Limitations and Future Research

There were some limitations to this research. First, time was a limitation. If I had more time, then I could have addressed the topics of my research in greater detail. Furthermore, I might have been able to do more than just one case study. This is something that is a possibility for future research; more case studies may be done to check if my approach is a correct one.

Furthermore, some aspects of calculating the carbon footprint have been discussed in this research, but could need some more research. I believe there are three topics of this thesis that could be investigated in more detail in a different research. First, more research should be done on the usefulness of IT for calculating a carbon footprint. Second, more research could be done on how to measure uncertainty in a carbon footprint calculation. For example, research could try to find out a way to produce a confidence interval for a carbon footprint. Third, research could focus on allocation. They could investigate whether allocating CO2 emissions to different outputs or among different faculties and departments would be worth the effort for universities, and they could explore ways to allocate emissions in more detail. Fourth, more research is necessary on how to incorporate emissions of investments (i.e. rebuilding) in the carbon footprint.

7.6 Recommendations to Erasmus University Rotterdam

The most important recommendation for Erasmus University Rotterdam is that they should calculate their CO2 emission every year. This is necessary in order to provide evidence for the 30% reduction in CO2 emissions that they want to achieve. Furthermore, lots of organisations are already calculating their CO2 emissions. Examples of these organisations are Lakeland Community College and the University of Toronto, which we discussed in this thesis. Furthermore, the TU Delft is busy with calculating their CO2 emission, and big Dutch companies like TNT Post and ProRail are reporting their CO2 emission yearly. The EUR has to keep up with this development and start reporting their CO2 emissions each year.

During this research, I have calculated the CO2 footprint of the Erasmus University Rotterdam. There are some improvements possible at EUR that would be helpful if a carbon footprint would be calculated another time. These possible improvements are especially about employee travel:

- Data about travels should be kept in a standard format. There should be a standard way of inserting the data for travelling registration, where city and country are registered into a separate column. It should be mandatory for employees to fill in the city and country of destination
- Faculties should add the mode of transportation for each travel
- Enter country and city names in one language only and use one name for each country
- Add the distance of the flight to each record

There are also some other emission categories where simple improvements in data collection could make the CO2 collection easier:

- In general: create a directory on the internet where all the data that is necessary for calculating the carbon footprint is stored or let every person that can deliver necessary data send it to the person that is calculating the carbon footprint before a certain date. At this moment, I had to contact a lot of people at EUR to get the data that I needed, which took me a lot of time.
- For commuting: do the mobility research every year. For 2010, I was lucky enough that a mobility research was done, but people would want to calculate the carbon

footprint for 2011 in the same way, then a new mobility research is necessary for 2011.

- For the mobility research, two additional questions can be asked:
  How many kilometres do you travel to the university each day?
  How many weeks per year do you travel to the university?
- Measure the weight of the swill, glass and confident papers to make sure that these weights do not have to be estimated.

The EUR could also choose to implement an information system for data collection and for the calculation. I recommend that the university would first calculate the CO2 footprint in a less expensive way (for example by using an Excel sheet like mine) for the first few years. After doing this, the university can do an evaluation and see whether an information system would be worth the costs.

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