Delft University of Technology
Faculty of Technology, Policy and Management

The combined carbon and water footprint of organizations

Developing a method that is able to support the determination of the combined carbon and water footprint of organizations

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Preface

This report contains the results of the Master Thesis project that I've performed from March to October 2009 at Ernst & Young Business Advisory Services in Rotterdam. Being the final step in acquiring my MSc. Grade for Systems Engineering, Policy Analysis and Management it has been an intensive and challenging period with a more than satisfying result.

The research was initiated by Astrid Wisse, Danny Siemes and Dietmar Laske, all three senior managers at Ernst & Young, interested in supporting the business decisions of multinational corporations to balance both financial and environmental performance. It is due to their dedication to this new field of research that a position was realized in which I could work on this topic for six months, fully supported by all necessary facilities, expertise and coaching.

I would like to express my gratitude towards Astrid Wisse from Ernst & Young, who has fulfilled the role as external supervisor next to her already demanding agenda as senior manager. By both coaching and guiding me through the sometimes challenging process and allowing me all the freedom and flexibility necessary to perform this research independently she has been an important factor in successfully performing this project. Also towards Danny Siemes for his sharp insights and role as the devils advocate during several discussions and being my mentor in introducing me to the challenging world of consultancy.

Furthermore I would like to thank Rens Kortmann as my first supervisor for his excellent style of coaching. During our numerous conversations he was able to keep me motivated and inspire me to take the extra step towards better results. Especially his optimism, sincere interest and commitment with which he has performed his role as my first supervisor have been very helpful to me. Another word of thanks I would like to express towards Zofia Lukszo as my second supervisor. Not only has she been able to support me with the content of my research but also she provided good advices for setting and realizing goals for personal development. Also I would like to thank Alexander Verbraeck for being the chairman of the committee and for sharing his experience and sharp insights.

Performing this research has been an intensive and challenging period. Therefore I would like to thank all my friends and family who have been so understanding and supportive. Especially Charlotte has been able to support me and motivate me to take some distance from the project, which allowed me to clear my mind and look at it from a different perspective for which I would like to thank her a lot!

And of course thanks to all those other people who have supported me during this research

Jouke Dessens

Delft, October 2009

Executive Summary

Increased public attention for climate change, more stringent regulation and corporate social responsibility programs force organizations to gain insight into their environmental performance. Carbon emissions caused by the combustion of fossil fuels increasingly influence the global temperature rising due to the greenhouse effects. The climate change has led to an increase in natural disasters around the world such as tropical storms, heavy rainfall and flooding due to the rise of the sea level. The water scarcity that is present in certain areas is expected to grow substantive resulting in 2 out of 3 inhabitants suffering from water shortage in 2025. Through Corporate Social Responsibility programs, today's organizations are acknowledging their responsibility in the society and the environment. The environmental impact of an organization becomes an important element of doing business. To be able to determine this impact it is necessary to gain insight into the actual environmental impact of the organization. The ecological footprint is a method that was already developed for this cause in 1962 by Wackernagel. Based on this concept the carbon footprint and the water footprint have been developed, determining the total carbon emissions and the freshwater usage due to activities. The combination of these indicators is expected to provide unique insight into the environmental impact caused by the activities of organizations. The tradeoff between reducing carbon emissions and water usage due to the adoption of bio-fuels is a good example of this. However, no theoretical foundation is currently available to determine the combined carbon and water footprint of an organization.

Ernst & Young Business Advisory Services phrased the demand for the development of an instrument that is able to support the determination of the combined carbon and water footprint, being important indicators of the environmental performance of organizations. This resulted in the following research question:

How can the combined carbon and water footprint of an organization be determined?

In order to answer this research question a design science approach based on Peffers (2007) was adopted to guide the research. The design science paradigm is based on the development of scientific knowledge by examining uncharted problems and solving them in novel ways in a rigorous fashion. This approach allows us to structure the research which has a twofold objective of developing an innovative artifact and creating knowledge.

A literature research identified two established concepts of the separate corporate carbon and water footprint which are chosen to form the basis for the development of the theoretical concept of the combined carbon and water footprint. The Greenhouse Gas Protocol as defined by the International Panel on Climate Change is a standard for determining the carbon footprint of an organization. The Business Water Footprint as developed by the UNESCO-IHE is a concept for determining the water footprint of an organization.

By identifying the links between the carbon emission sources and water usage sources of the organization and adopting the scope of both established concepts, we developed a conceptual model of the combined carbon and water footprint of an organization. The conceptual model takes into account the organization for the direct footprint and the inbound, the outbound and the support part to determine the indirect footprint. The direct footprint of the organization contains the carbon emissions and water usage sources of the production of electricity, heat and steam; also it contains

the transportation in company-owned vehicles, the production and manufacturing processes, leakages and the extraction of water from the municipal supplies. The inbound part consists of the carbon emissions and freshwater usage due to the generation of purchased electricity, heat or steam and the extraction and production of materials, goods and products purchased into the organization. The outbound part contains the carbon emissions and water usage due to the use of sold products and services and the disposal of waste. Finally the support part of the organization contains the carbon emissions and water usage due to the leased assets and outsourced activities and also due to the transportation in vehicles which are not owned by the organizations.

After calculating the footprint, the interpretation of the results requires specific attention. Carbon emissions are a location independent phenomenon. However, the geographical component of the water footprint is essential to the interpretation of the results. The impact of the evaporation of water depends on the geographical location at which this takes place. Evaporating 1.000m^3 of freshwater in Ghana has a total different meaning than doing this in the Netherlands. For interpreting the values determined in a water footprint study insight into this geographical location is essential.

Based on the conceptual model and the design requirements of Ernst & Young an instrument has been developed that is able to assist the determination of the combined carbon and water footprint. Due to the requirements set by Ernst & Young the design challenge was formed by the extensive calculation process of the combined footprint being constrained by limited budget of time. This resulted in an instrument implemented into a spreadsheet program. The instrument was evaluated by performing two case studies and obtaining an expert opinion. Main findings for application of the instrument are a limited application domain and the range of expected errors of the results. Five guidelines were developed which must be followed during application of the instrument. First guideline is to ensure the match between the type of organization and the application domain. Second there must be sense of urgency at the client's organization. Third, the required information must be available. Fourth, an administrator must be appointed for supervision on maintenance and usage of the instrument. And fifth, the future users of the instrument must have basic knowledge of footprints in order to apply the instrument.

The answer to the main research question is twofold. First, the combined carbon and water footprint of an organization can be determined by applying the developed spreadsheet model, following the six-step approach with respect to the developed guidelines for applying the instrument. In those cases the application of the instrument proves to be a good method for determining the combined carbon and water footprint of an organization. Second, the combined carbon footprint of an organization can be determined by applying the theoretical conceptual model following the six-step approach. This will result in a tailor made solution that fits the specific organization that is topic of study.

The developed spreadsheet model is the result of the specification of the calculation of the combined carbon and water footprint under the requirements that were defined by one client. In cases in which the requirements are different or when the conditions of applying the model can't be met, the second approach is advised. The conceptual model provides the theoretical foundation for determining the footprint and is guided by the six-step approach. This approach enables the general application of the developed concept although it does require expertise in the field of footprints by those who apply it.

The developed instrument is useful to gain into the combined carbon and water footprint of an organization. In its current state it can be applied to provide first insight to an organization without large research efforts. This provides the opportunity for Ernst & Young to perform quick-scans of clients as basis for further actions. The results can be used to identify the areas in which the potential lies to develop possible measures of reducing the footprint. However for detailed insight into the footprints additional research is required into specification of the calculations and adding conversion factors.

Future research is recommended into four directions. First, including the geographical component of the water footprint in reporting the results adds meaning to the outcomes. The suggested approach of using the water scarcity index is expected to provide a good basis for further developments. This would enable the possibility to report on the actual impact of the footprint of the organization, in addition to its size. Second, additional ecological indicators can be added to the conceptual model. The chosen combination of carbon and water is based on the existing tradeoffs between these two indicators. Adding more ecological indicators to the calculation of the environmental impact of the organization is expected to lead to better insights. Possible elements are land use and extraction of non-renewable resources. Third, additional research is advised to determine the trade-off between the different ecological indicators. The conceptual model as it has been developed does not facilitate the tradeoff between them. This requires specification of the expected impacts or other means of comparison. Possible outcome of this research effort can be a framework which supports decision makers within the organizations. Fourth and final recommendation is the further application of the defined concept of the combined carbon and water footprint of organizations. We encourage researchers and practitioners to use the developed conceptual model, the approach and the developed spreadsheet model. We expect that additional experience leads to improvements and further developments of these concepts when applied in future research.

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1 Introduction

If you were the CEO of a large multinational firm wanting to improve the sustainability of your organization, what would you decide: spend your budget on bio-fuel cars to replace the current car park or switch to a green energy supplier producing sustainable energy? On what grounds would you be making this decision? What would be the influence of both options on the overall environmental impact of your firm and which one would result in the most positive effect on the environmental performance of your organization? What is the current impact of the organization on the environment and do these proposed measures have significant influence on this or would your investments results in nothing but marginal improvements? These questions represent the dilemmas today's executives are faced with. In addition to the more traditional economical and financial aspects, the matters of climate change, air pollution and scarcity of resources play an ever more important role in the decision making process. To be able to make these decisions effectively it is necessary to gain insight into the environmental impact of organizations. This research has been performed to develop a theoretical foundation of the combined carbon and water footprint to enable the construction of an instrument that is able to determine the environmental impact of the organization.

This chapter introduces the topic of this master thesis report. It discusses the research background which explains the research problem. Next the research question is stated. Also the adopted research method is described and the outline of this master thesis report is presented in order to provide guidance for reading this document.

1.1 Research background: Environmental impact of business activities

Today's daily activities of individuals, companies, cities, countries or other entities are leaving their marks on our planet. The global temperature shows an increase over the past five decades up to 6°C. The International Panel on Climate Change created six different scenarios for the average global temperatures in 2100. Their predictions vary from an increase of 2°C up to the 11°C, causing an impact that will force its consequences into the daily lives of all inhabitants of the world (IPCC, 2008).

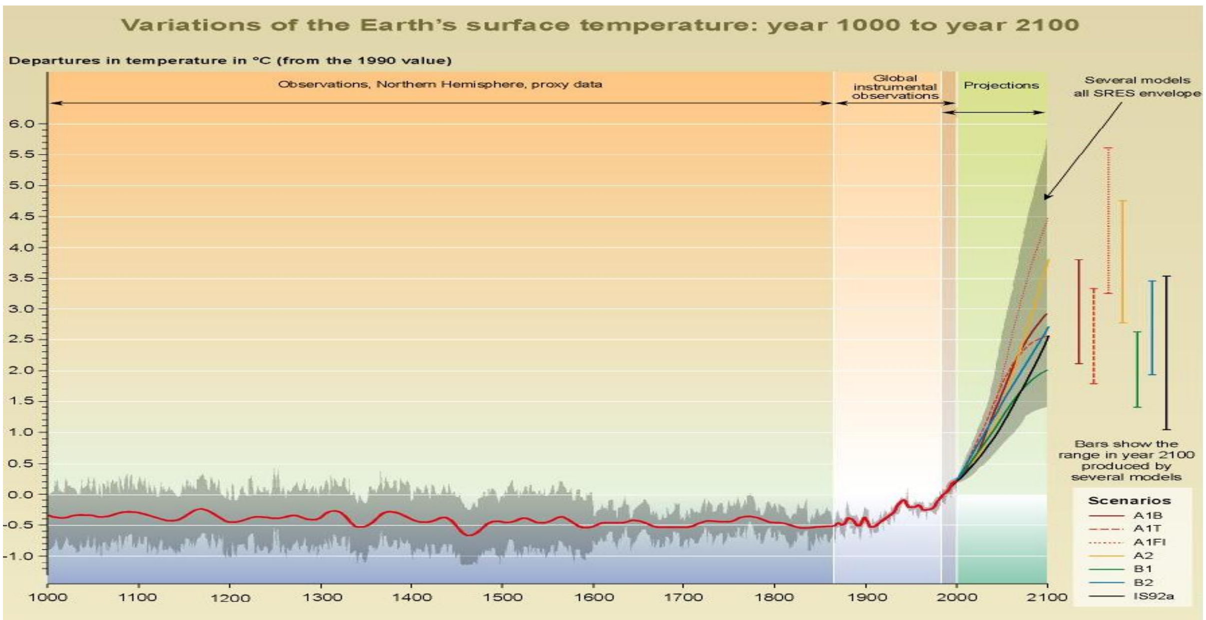


Figure 1 IPCC Global Temperature Estimation, (IPCC, 2007)

Already in 1962 this effect was acknowledged and formed the basis for the development of a method to gain insight into the actual impact that humans have on our living environment (Wackernagel, 1962). He describes the concept of the ecological footprint as:

"the Ecological Footprint is a measure of the 'load' imposed by a given population on nature. It represents the land area necessary to sustain current levels of resource consumption and waste discharge by that population"' (Wackernagel, 1962).

Hereby he proposes to translate the earth's available resources into the amount of land needed for the earth to be able to sustain the behavior of its inhabitants. Anno 2009 the current way of living of the average human being requires 1.4 times the amount of land available on our planet (WWF, 2009). Measuring our impact in terms of ecological footprint allows us to gain insight in the true size of the matter. Additional research has been performed and resulted in the further development of the footprint concept. The term 'carbon footprint' has become common in today's language. The concept of the carbon footprint was defined by the Carbon Trust as:

"the total set of greenhouse gas emissions caused directly and indirectly by an individual, event, organization or product expressed as carbon dioxide equivalents" (EABIS, 2009).

This definition has been widely adopted and applied in numerous cases. The impact of the emission of greenhouse gasses today is widely discussed by scientists, businesses and governments all over the world. The relation between carbon emissions and climate change was topic of many studies and has been proved to exist and to be positive (Scheffer, 2005). Al Gore has published his 'Inconvenient Truth' in an attempt to get the carbon on the political agendas all over the world and thereby spread the concept of global warming among large parts of the Western world.

Another ecological indicator that is developed is concerned with the status of the fresh water resources on the planet. The water scarcity concept was introduced by the World Health Organization and the United Nations Environment Program. With the current population of 6.4 billion, and an annual increase of 80 million, this will result into the situation in 2025 that 2 out of 3 persons on Earth will experience water stress (Larsen, 2008). Even though almost 70% of the world's surface is covered with water, only 2.5% of this can actually be consumed and the rest of this is salt water. Of this 2.5%, almost two third is confined to glaciers and snow cover. This results into water being a scarce resource (WHO, 2009). This focus on freshwater is important due to the fact that only 3% of the water on the earth is freshwater and therefore has the characteristic of a scarce resource in some areas (Gleick, 1993).

Linked to the development and acknowledgement of water scarcity, the concept of the water footprint was developed. Hoekstra created the concept of the water footprint to be able to determine the total amount of water that is used to produce goods and services. Since the agricultural sector accounts for almost 70% of all water usage worldwide (Hoekstra, 2004) this concept started to develop based on research in the agricultural sector. Hoekstra defines the water footprint of a business as:

"the total annual volume of freshwater that is used directly or indirectly to run and support a business" (Hoekstra, 2004).

Instruments that are able to determine the water footprint of a business currently do not exist. This field of research is still going on and subject to many international conferences such as the World Water Forum in Istanbul in 2009 (Lopez, 2008).

The concepts of the carbon and water footprint have established a field of research that is concerned with the environmental impacts of various activities. Research into the effects on the carbon emission and freshwater usage in the production and usage of bio fuels has indicated that although the adoption of bio-fuels causes a reduction of carbon emissions and solves a problem it causes another problem. This due to the fact that for the production of bio-fuels the total fresh water usage is between 70 and 400 times larger compared to the water usage for the production of fossil fuels, which can lead to large problems in water scarce areas (Lopez, 2008). By combining the water and the carbon footprint more insight is created in the actual impacts of different activities. In case of comparing the environmental impact of traditional, fossil fuels and the upcoming, bio fuels for combustion in engines this combination leads to better insight.

Nowadays the majority of the large companies such as Shell, Heineken, Ahold, Unilever and Nuon has adopted a social responsibility program in their mission statement. Corporate social responsibility programs aim at achieving sustainable development of the companies. A definition is:

"Corporate Social Responsibility is the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large" (Holme, 2009).

The large effort invested in these programs indicates the importance of the corporate social responsibility (CSR) for these businesses (EABIS, 2009). The financial annual reports have been extended to reporting the environmental impact of companies as well. Insight into the environmental performance of companies is the main input for the corporate responsibility annual reports that earlier mentioned companies present as part of their annual reports. Due to the large interest in reporting the environmental performance of companies the Global Reporting Initiative started in 2002 to develop guidelines for environmental reports in businesses (G.R.I., 2009). In 2008, 940 companies from all over the world voluntarily used the G.R.I. guidelines to set up their annual sustainability reports. Already in 1987 the sustainability concept was defined by the World Commission on Environment and Development. The WCED defined a social, economic and environmental aspect of sustainability (WCED, 1987). This concept has been widely adopted by companies and also governments as the 3 P's: people, planet, profit. The Dutch ministry of Agriculture, Nature and Food Quality defines social corporate responsibility as doing business with taking into account 'people', human beings within and outside of the company, 'planet', consequences for the environment and 'profit', the production and economic results of goods and services (Min ANFQ, 2009).

In order to report the environmental performance of a company, this has to be measured and determined first. The Ecological Footprint is an appropriate instrument to gain insight into the environmental performance of entities, such as companies (Kitzes, 2008). The large interest in the developments of footprints has resulted in the founding of the Global Footprint Network which aims at accelerating the worldwide usage of the Ecological Footprint as an indicator for sustainability (GFN, 2009). In order to measure the impact of organizations on their environment the ecological footprint can be determined. This can be used as an indicator for the environmental performance.

1.2 Research problem: Insight into the environmental impact?

Insight into the carbon emissions and the water usage of organizations is required to determine the environmental impact of the organization. No instrument is currently available to determine the carbon and water footprint and neither is the theoretical foundation to develop such an instrument. This results in the current situation in which we are unable to provide the necessary insights in these factors to support decision making processes.

Ernst & Young Business Advisory Service, department Multinational Clients, has phrased the demand for developing an instrument that is able to assist organizations in gaining insight into the combined carbon and water footprint. This leads to the practical objective of designing an instrument that enables Ernst & Young to assist companies in determining their combined carbon and water footprint.

Before the instrument can be developed a theoretical basis is required to serve as foundation for the instrument. The concept of a combined carbon and water footprint of organizations has not been developed yet. This identifies the gap between the current and demanded situation and leads to defining the main research question:

How can the combined carbon and water footprint of an organization be determined?

Answering this research question is expected to result in a general approach which guides the process of determining the carbon and water footprint of an organization. In order to answer this question the following sub questions have been articulated.

- **What concepts for determining the carbon and water footprint can be derived from literature?**
- **What conceptual model for the combined carbon and water footprint of an organization can be designed based on existing concepts?**
- **What are the requirements for an instrument that is able to calculate the combined carbon and water footprint of an organization?**
- **What instrument can be developed that is able to calculate the combined carbon and water footprint of an organization?**
- **To what extend is the instrument successful in determining the combined carbon and water footprint of an organization with respect to the requirements?**
- **What approach can be stated for determining the combined carbon and water footprint of an organization?**

1.3 Research approach: Design Science Research Methodology

In order to successfully answer the research question it is necessary to adopt an appropriate research approach to structure and guide the research. For this research the design science research methodology as proposed by Peffers is adopted as basis for the research approach. (Peffers, 2007). The design science paradigm was defined as the research approach that is aimed at adding to the body of existing (scientific) knowledge by examining uncharted problems and solving them in novel ways in a rigorous fashion (Hevner, 2004). The objective of design research is twofold; it is aimed at creating utility (an applicable artifact) and knowledge (contribution to existing knowledge). An important distinction has been made between the routine of design and design science. Design is the application of knowledge to solve a previously examined problem; this is the application of best practices to well understood problems. Design research addresses heretofore unsolved problems by solving them in novel and innovative ways (Hevner, 2004).

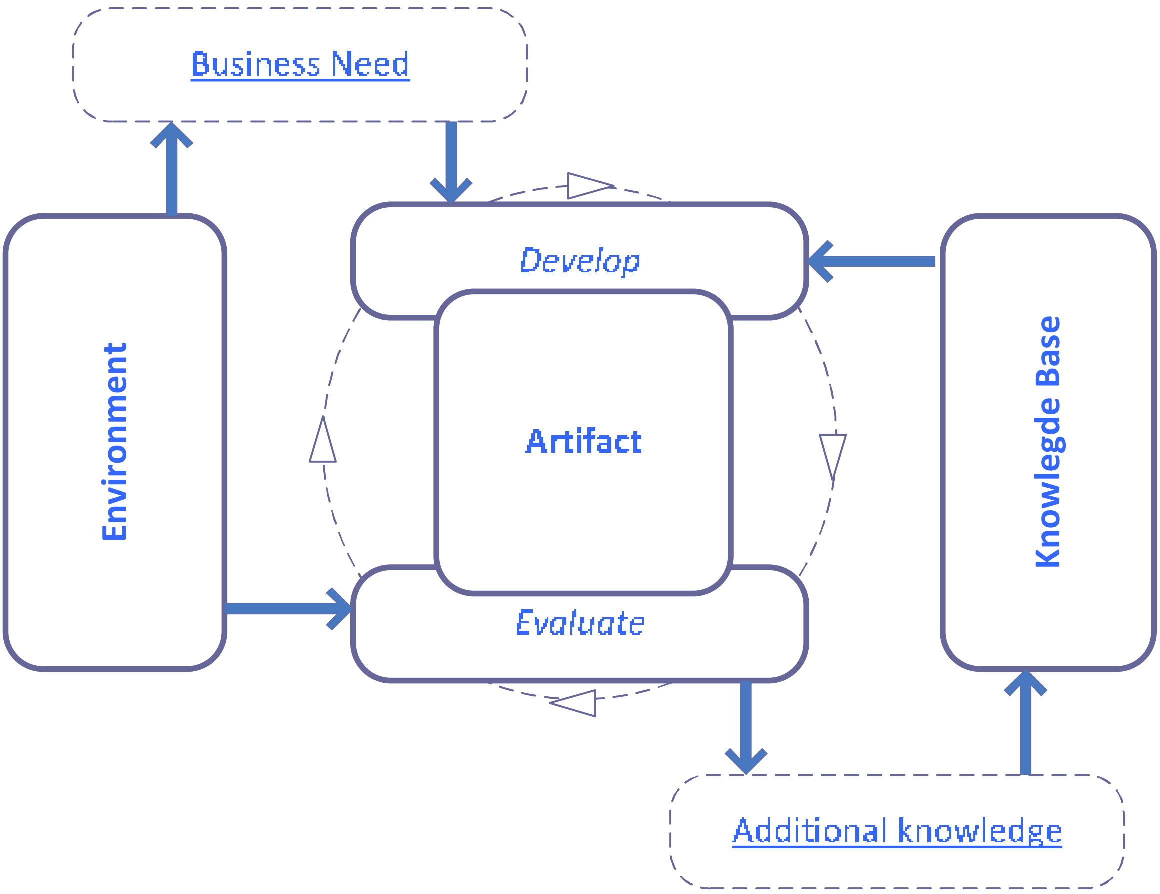


Figure 2 Design science paradigm, (based on Hevner, 2004)

Figure 2 represents the design science paradigm as defined by Hevner. The environment defines the solution space in which the phenomena of interest are residing (Simon, 1996). In the environment the businesses, people, goals, tasks, problems, and opportunities are present that together define the business needs as perceived by people within the organization (Hevner, 2004). Based on the business needs the development of an artifact can be initiated. Methodologies, constructs, standards, theories and other existing knowledge can be extracted from the knowledge base concerning the specific phenomenon of interest. The two activities performed in design science research are build and evaluate, build is the development of the artifact and evaluate the evaluation of the artifact in respect to the context in which it is situated (March, 1995). The design process that is aimed at incorporating the knowledge from the knowledge base into the creation of a problem to the identified business need, resulting into the artifact can be characterized by creativity, capriciousness or as an arbitrary process (Brooks, 1987). The design effort takes place in different rounds in which a new prototype is developed, tested and improved until the requirements are met, following the spiral model of Boehm (Boehm, 1994). Using rigorous methods for the evaluation of the design it is expected that knowledge can be contributed to the existing knowledge base. Thereby distinguishing design research from a regular design effort.

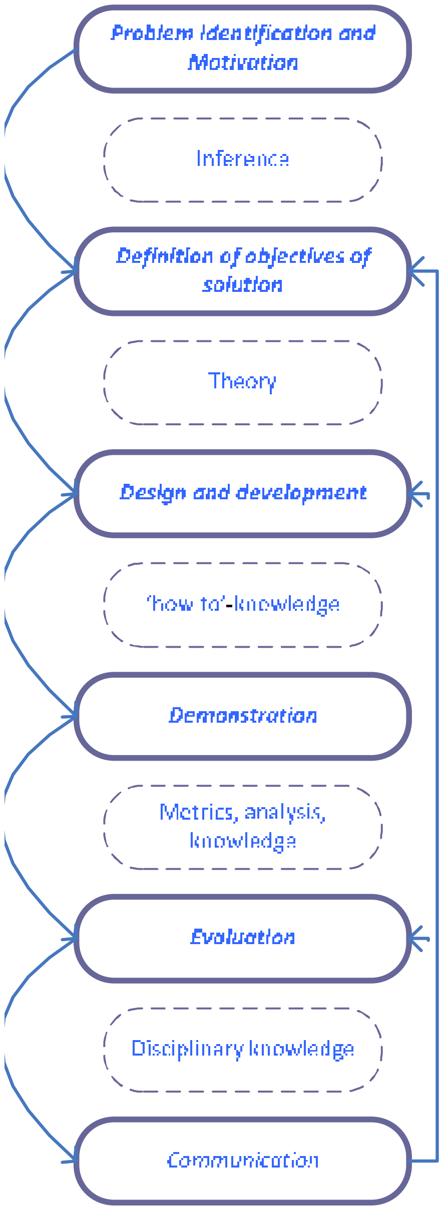


Figure 3 Design Science Research Methodology

The research approach that is adopted is based on the Design Science Research Methodology (Peffer, 2008). This is the first applicable methodology for performing good design science research, based on the present available literature in this field (Peffer, 2008). This approach distinguishes six different phases of research starting with problem identification and ending with communication of results. Iterations between the different phases are possible and sometimes necessary. For example iterations in the cycle of design, demonstrate and evaluation is performed several times to improve the design.

The first activity is defining the specific research problem and justifying the research effort by defining the expected added value of a solution. This requires insight into the problem conceptually using specific knowledge on the state of the problem. This results in clear understanding of the problem which is to be used to establish the objectives of the solution in the next phase. The objectives of the solution provided by the designed artifact must be specified based on the problem identification, using both the existing theories and knowledge of the problem domain and the environment in which the artifact will be used. Specifying the objectives into requirements creates clear insight into the demands to the artifact.. The actual design of the artifact includes determination of the artifacts functionality, architecture and the creation of the artifact. When finished the prototype is demonstrated by using experimentation, simulation or case studies. The results of the demonstration are used for the evaluation. The evaluation of the artifact is to observe how well the artifact is supporting the solution of a problem. It includes the comparing of the stated objectives to the actual observed results from the demonstration of the artifact. Based on the results it can be decided to iterate to the design phase to improve or to proceed to the next phase. The last phase of the design science research methodology is to effectively communicate the problem and its importance, the artifact, the utility and novelty, the rigor of the design and its effectiveness both to researchers and to practicing professionals.

Hevner has introduced the design-science paradigm that adopts the thought that building and applying designed artifacts results in the achievement of knowledge and expertise of a problem domain if performed correct (Hevner, 2004). To assist researchers in performing effective design research Hevner proposes seven guidelines that lead to successful performance of design research. To ensure that this research will result into good design-research, attention will be paid to these guidelines in addition to the adopted Design Science Research Method.

"….design-science research requires the creation of an innovative, purposeful artifact (Guideline 1)"

This research is focused on designing an instrument that is unique in its ability to determine the combined carbon and water footprint of an organization, it can be stated that by definition the aim of designing an instrument can be seen as an attempt to create a purposeful artifact. The model's purpose is directly yielding utility for its application in determining the environmental impact of organizations.

"…aimed at solving a relevant problem in a specified problem domain (Guideline 2)"

The problem domain that is topic of this research is the domain of the ecological footprints of organizations. This recently developed field of research that originates from the concept of the ecological footprint of Wackernagel in 1998 and has been developing ever since. In the current stage of research the proposed design research contributes directly to relevant problems existing in this field as explained in the research background.

"…..thorough evaluation of the artifact is crucial (Guideline 3)"

Thorough evaluation of the artifact is defined by Hevner as demonstrating the utility, quality and efficacy by means of well-executed evaluation methods. This will be an important part of this research allowing the determination of the value of the instrument in both its application and scientific contribution.

"…..the artifact must be 'innovative' solving a heretofore unsolved problem (Guideline 4)"

This fourth guideline implies the research results must be contributing to the design artifact, foundations and/or methodologies available in the current knowledge base. The expected results of this research are contributing new insights into at least two of these fields. The model can be classified as an innovative artifact since it is unique in its ability to gain insight into the combined carbon and water footprint of an organization.

"…..the artifact itself must be rigorously defined, formally represented, coherent, and internally consistent (Guideline 5)"

Design research must be conducted 'rigorous'. Adopting effective theoretical foundations and research methodologies adds rigor to this research. Due to the explorative character of design-research the adoption of proved methods adds rigor to the research. By adopting a design method that is established in literature and the intention to use rigor validation methods this guideline is adopted.

"…..the process by which it is created, and often the artifact itself, incorporates or enables a search process (Guideline 6)"

The design process of the model is expected to be a search process due to the necessity to perform exploratory research and make us of iterations. By generating possible alternatives, testing and improving them the appropriate solution is searched for.

"…..the results of the design science research must be communicated effectively (Guideline 7)"

After this research is completed the results are communicated to a business practical audience as well to a scientific audience. The source of the citation of the guidelines is the article of Hevner (Hevner, 2004).

1.4 Thesis Outline

In order to answer the research question the research will be performed in three different stages. The first part will be dedicated to the theoretical foundations of the carbon and water footprint. This results in proper understanding of the research problem and the proposal of a conceptual model for the combined carbon and water footprint of an organization. The second part of the report is concerned with the application of the theoretical concept into an applicable instrument to determine the combined carbon and water footprint of an organization. The context of application, the requirements and the actual design are discussed in this part. The third and final part is concerned with the evaluation of instrument based on the stated requirements. Different rigorous evaluation methods are applied to determine to what extent the instrument is successful in fulfilling the requirements. Based on the results from the application of the conceptual model into a practical applicable instrument, the conceptual model is evaluated and suggestions for improvements are stated.

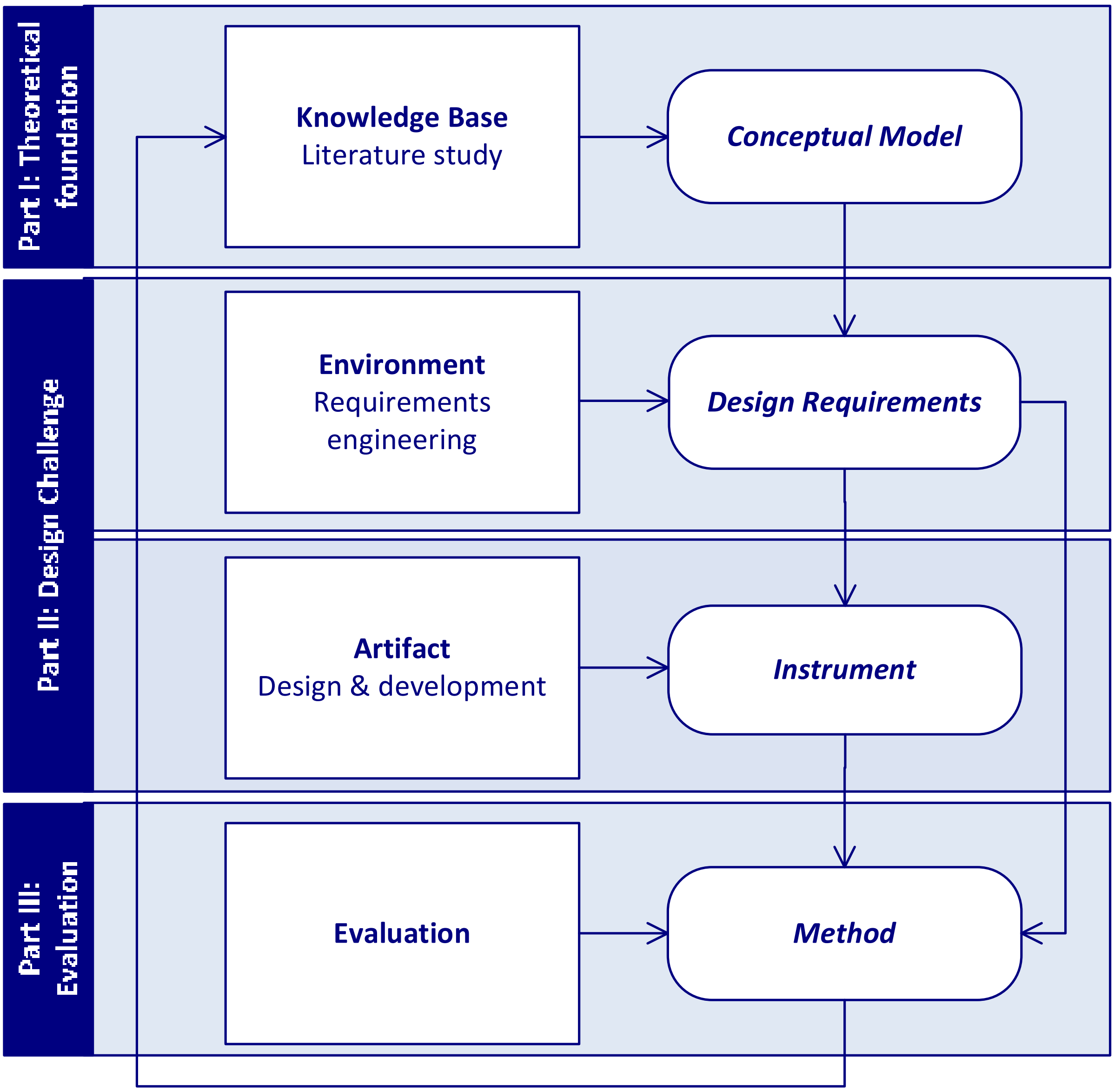


Figure 5 Used research approach

This results in the following outline of this master thesis:

Part I: Theoretical foundation: conceptual model for the combined carbon and water footprint

Chapter 2: What concepts for determining the carbon and water footprint can be derived from literature?

Chapter 3: What conceptual model for the combined carbon and water footprint of an organization can be designed based on existing concepts?

Part II: Design challenge: an instrument for E&Y based on the conceptual model

Chapter 4: What are the requirements for the instrument that is able to calculate the combined carbon and water footprint of an organization?

Chapter 5: What instrument can be developed that is able to calculate the combined carbon and water footprint of an organization?

Part III: Evaluation: performance of the instrument

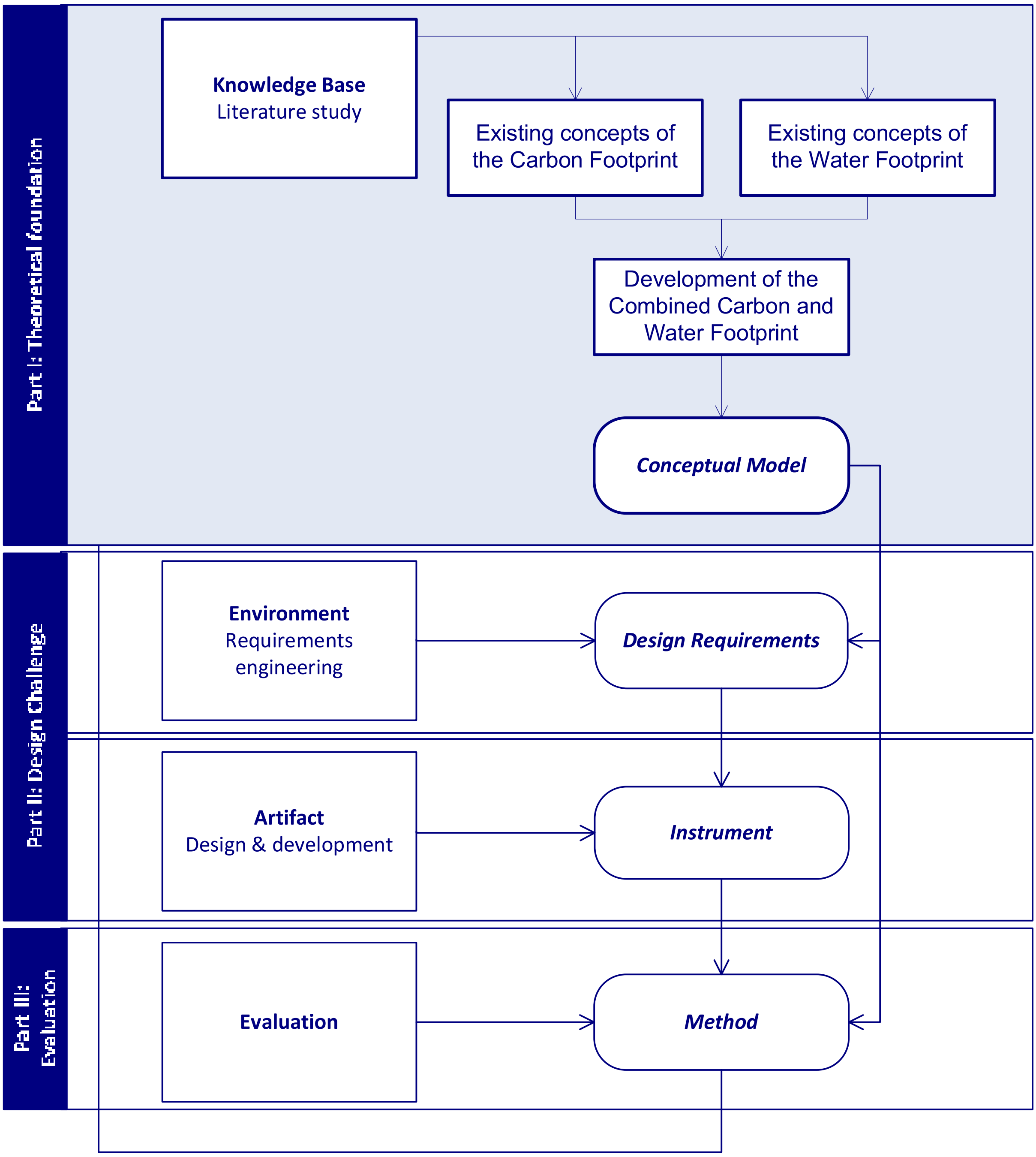
Chapter 6: To what extend is the prototype successful in determining the combined carbon and water footprint of an organization with respect to the requirements?

Chapter 7: What approach can be stated for determining the combined carbon and water footprint of an organization?

Part IV: Conclusion: conclusion and recommendations

Chapter 8: Conclusion: How can the combined carbon and water footprint of an organization be determined?

Part I



Part I: Theoretical foundation: conceptual model for the combined carbon and water footprint

Chapter 2: What concepts for determining the carbon and water footprint can be derived from literature?

Chapter 3: What conceptual model for the combined carbon and water footprint of an organization can be designed based on existing concepts?

2 Theoretical concepts of the carbon and water footprint

- What concepts for determining the carbon and water footprint can be derived from literature? -

This chapter describes the results of the performed literature study into existing concepts to determine the carbon footprint and the water footprint of organizations. First the existing knowledge in literature and practice is discussed for both the carbon and the water footprint. For both concepts the definitions, methodologies, standards and practical experiences available in literature are discussed and the elements that are relevant for the development of the conceptual model of the combined carbon and water footprint of an organization are stated. After the description of the existing concepts, the elements of both concepts that are relevant for determining the combined carbon and water footprint are presented.

2.1 The Carbon Footprint concept

2.1.1 Definitions of the Carbon Footprint

Various definitions of the carbon footprint are present in literature. A literature review performed in 2008 identified eight different definitions.

Source	Definition
BP (2007)	"The carbon footprint is the amount of carbon dioxide emitted due to your daily activities – from washing a load of laundry to driving a carload of kids to school."
British Sky Broadcasting (Sky) (Patel 2006)	The carbon footprint was calculated by "measuring the CO_2 equivalent emissions from its premises, company-owned vehicles, business travel and waste to landfill." (Patel 2006)
Carbon Trust (2007)	"… a methodology to estimate the total emission of greenhouse gases (GHG) in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (excluding in-use emissions). "… 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 (we [The Carbon Trust] will refer to this as the product's 'carbon footprint')." (CarbonTrust 2007, p.4)
Energetics (2007)	"… the full extent of direct and indirect CO_2 emissions caused by your business activities."
ETAP (2007)	"…the 'Carbon Footprint' is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced, measured in tonnes of carbon dioxide."
Global Footprint Network (2007)	"The demand on biocapacity required to sequester (through photosynthesis) the carbon dioxide (CO_2) emissions from fossil fuel combustion." (GFN 2007; see also text)
Grub & Ellis (2007)	"A carbon footprint is a measure of the amount of carbon dioxide emitted through the combustion of fossil fuels. In the case of a business organization, it is the amount of CO_2 emitted either directly or indirectly as a result of its everyday operations. It also might reflect the fossil energy represented in a product or commodity reaching market."
Paliamentary Office of Science and Technology (POST 2006)	"A 'carbon footprint' is the total amount of CO_2 and other greenhouse gases, emitted over the full life cycle of a process or product. It is expressed as grams of CO_2 equivalent per kilowatt hour of generation (gCO_2eq/kWh), which accounts for the different global warming effects of other greenhouse gases."

Figure 6 Definitions of the carbon footprint - (Minx, 2008)

The definitions that are found in this brief literature review have various meanings. Similarities can be found in the fact that all definitions represent some amount of carbon emissions; main difference is caused by the focus that is chosen and the sources of these emissions that are taken into account.

The focus chosen by BP is the individual human being that needs to calculate all carbon emissions due to their daily activities. Patel and Energetics choose the focus to the carbon emissions of an entire organization, still differences can be found in the description of the sources, '..emissions caused by your business activities' versus '...its premises, company owned vehicles, business travel and waste to landfill'. The definition stated by ETAP is concerned with the total carbon emissions due to all human behavior on the planet. The Global Footprint Network also chooses the scope of all human behavior, but it defines the footprint as global hectares necessary to compensate for all emissions caused by the combustion of fossil fuels. Grubb & Ellis choose to state several definitions, first the emissions due to combustion of fossil fuels, which can be calculated focused on a business organization' daily activities, but also the amount of fossil fuels that was necessary to produce product or commodity. The Parliamentary Office of Science chooses the product life cycle and expresses it as the amount of carbon emissions necessary to produce electricity that is consumed in by the product.

Comparing these eight definitions clearly demonstrates the importance of accepting one definition of a carbon footprint to avoid confusion. When for example the outcomes of carbon footprint studies are used for comparison it must be sure that both studies use the same definition. Otherwise the results of the calculation cannot be used to be compared.

The definitions as occurred in the literature study mentioned above show three different elements that determine the definition. First the entity that is chosen defines the subject to the carbon footprint study. This can be an individual, activity, organization, population or any other entity. After having defined the entity the sources that are taken into account need to be defined. And the scope that is chosen to perform the footprint study with is relevant for the outcomes which determine the boundaries of what is taken into account in the footprint and what isn't. Before it is made explicit what the choices are in a definition of the carbon footprint, the outcomes cannot be interpreted. These differences in the definitions complicate comparison of the measurements that are available since it is unclear what definition actually was adopted in large number of studies (Johnson, 2008).

2.1.2 Methods for determining the carbon footprint

Different methods for determining the carbon footprint are available. The bottom-up approach is based on process analysis and breaks down the total process into smaller elements, until the source of the emissions is reached. Setting the boundaries for a bottom-up performed carbon footprint study plays an important role. Taking into account certain elements and leaving out others determines to large extent the outcomes of the footprint. These characteristics of the bottom-up approach cause the method to be subjective, since these choices are made by the analyst. Also the amount of information that needs to be gathered for this type of studies is large. Breaking down the activities performed within the defined entity leads to specific insights but also requires specific information (Carbon Trust, 2009).

Clear example of the bottom-up approach is the life-cycle assessment method. The life-cycle assessment (LCA) is a method to determine the environmental impacts of a product or service from 'cradle to grave'. This is the investigation and valuation of the environmental impacts of a given product or service caused or necessitated by its existence. Following the theoretical grounds, all the processes, affected by the life cycle of a product or service, have to be taken into account. This leads to problems when this concept is applied in practice: it requires a large amount of data to be collected. In practice a trade-off has to be made between information accuracy and the amount of data that needs to be collected (Wenzel, 1997). A good example of the quick expansion of the complexity is given by (Wenzel, 1997) that describes the life cycle of a bottle of wine.

…..for a simple bottle of wine the processes in the life of the wine bottle are:

- Extraction and processing of raw materials: Sand, limestone, soda etc.

- Manufacturing the wine bottle at a glasswork

- Filling of wine into the wine bottle and corking

- Use (drinking the wine)

- Recycling (rinsing and refilling) or recycling (re-melting at a glasswork)

- Use

- Recycling….

- Disposal as household waste

- Transport in between all these processes

- Furthermore, these processes demand a lot of other processes, e.g.:

- Production of electricity and other energy types and extraction of raw materials for this

- Production of water (for rinsing)

- Production of chemicals for rinsing the wine bottles

- Production of materials for all the suppliers of the glasswork, for the soda production etc.

- Production of buildings, machines, trucks, tires, roads etc. and production of materials for this (e.g. steel) – also for all the suppliers and for building the electricity work etc.

……..This list is endless. The glassworks has suppliers, and each of these suppliers has suppliers, and these suppliers also have suppliers……..

This example shows that if applied according to the formal definition, a LCA requires a seemingly unlimited amount of data. If applied to another product for example a car or an airplane this problem becomes even larger since they have many more components. Unless there is access to unlimited resources for conducting the LCA study and all information is available, a LCA will never be complete and will always be influenced by the boundaries that are chosen. This indicates one of the main characteristics of the bottom-up approach; it provides insight into large detail but also requires input in large detail.

Another method to perform a footprint study is the top down approach. The most common example of the top down approach is based on Input-Output Analysis as used in economical studies. This method makes use of so called Input-Output tables. These tables contain data which represent the monetary transactions that take place within and between sectors in a national economy (Guinnee, 2008). Input-output tables are updated and published by national governments with a delay of 2-3 years. The characteristics of these tables, such as the level of detail of the information used, the monetary unit or the amount of sectors, differ per country. The information on the transactions is used to calculate the amount of carbon emissions caused during the production of goods and services. First the monetary flows due to the existence of a service or product are determined. The next step is to add environmental numbers into the analysis: for every monetary unit spent within a certain sector, an average emission factor is determined. By combining the monetary flows and multiplying them with the environmental indicators, the total amount of emissions due to the expenses of a specific organization can be determined (Zhao, 2009). A large advantage of this method, called 'Environmental Input-Output Method' is its ability to take into account all higher order impacts and sets the whole economy as its system boundary (Minx, 2007). This means that the entire supply chain can be taken into account (although some problems with crossing of national border might occur) (Hendrickson, 2004). This method has to make use of aggregated data, large amounts of assumptions and thereby produces outcomes that can be used for general indications or high level conclusions but is not applicable to specific cases (Minx, 2007). Lenzen has defined five different types of uncertainty that arise when using the IO method. The source data contains uncertainty, due to standard errors in data sources and the summation of these numbers causes uncertainty. The assumptions made on imported products and goods also cause uncertainty due to the large differences in emission factors per country. Another aspect is the proportionality assumption that assumes the costs per product to be the same, regardless of the industry in which the transaction takes place and the amount of the product being transferred. Also the aggregation of the data over a number of producers within one sector causes loss of detail and therefore uncertainty when coming to conclusions on specific cases. Finally the uncertainty that comes into being when allocating transactions over product ranges within the same industry, due to product diversity and co-production adds further to the uncertainties (Lenzen, 2000).

In between the contradicting methods of 'top-down' and 'bottom-up' there is a so called 'hybrid' form that aims at integrating both methods. Sangwon and Nakamura (Suh, 2007) provide an overview of five years of research in the field of Input-Output and Hybrid life cycle analysis. They state that by combining the Input-Output analysis with a process based LCA analysis the best of both worlds can be used. By combining the process-specific information for the foreground systems with the aggregated data for the entire economy for the background systems the best of both can be obtained. The required level of detail remains, and is supported by the IO data to overcome the boundary problems. Also (Nielsen, 2000) states that the basis of all process-based hybrid analysis methods is the assumption that the errors in the IO model (e.g. due to aggregated data) can be decreased or even avoided by adding process specific information. This approach offers the IO tables as an additional source of data collection, in case the bottom-up approach is not possible or requires too much effort in data collecting.

2.1.3 Standard of the Business Carbon Footprint

The World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) together developed the Greenhouse Gas Protocol in 1998. The Greenhouse Gas Protocol (GHGP) is an international accounting tool for government and business around the world to understand, quantify and manage greenhouse gas emissions. Since 1997 the founding organizations have been developing the protocol in close co-operation. The World Business Council for Sustainable Development (WBCSD) is a global association of almost 200 international companies that is dealing with business and sustainable development (WBSCD, 2009). The World Resource Institute is an environmental think tank founded in 1982 and is based in Washington (US) with the 'intention to protecting the Earth and improving people's lives' (WRI, 2009). This resulted in 2006 to the adoption of the Corporate Standard, a suite of calculation tools to assist companies in calculating their GHG's, by the International Organization for Standardization (ISO) and formed the basis for ISO-14064-I. Also the GHGP published 'A Corporate Accounting and Reporting Standard' containing two separate but linked standards on the accounting and reporting of GHG and also for the quantification of reductions from GHG mitigation projects. This calculating framework is in line with the European Union Greenhouse Gas Emissions Allowance Trading Scheme (EU ETS) and is applied in many other standards.

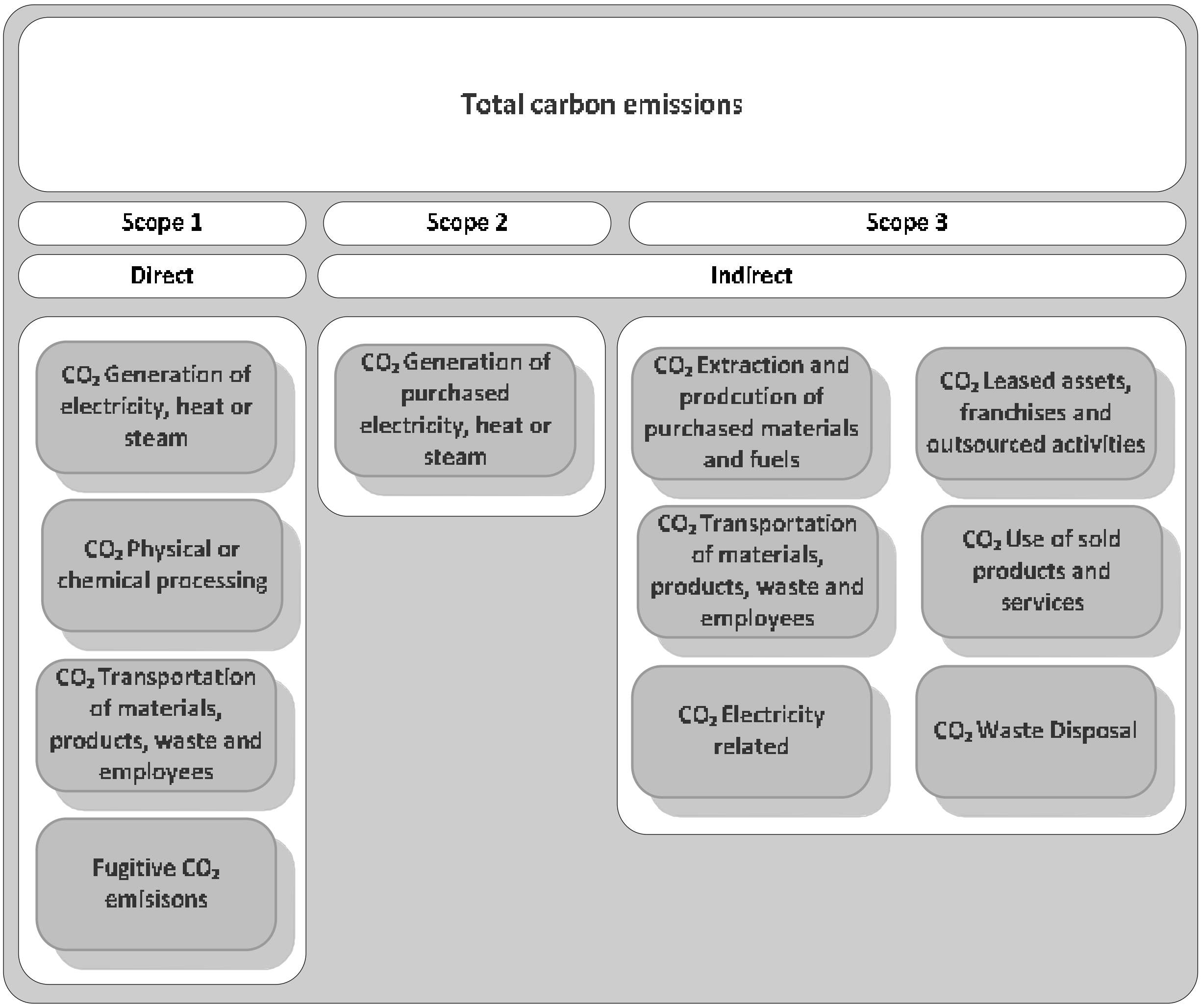


Figure 7 Overview of carbon emission sources of an organization, (IPCC, 2008)

The GHG protocol defines three different scopes in which carbon emissions of an organization can be taken into account. Scope 1 and 2 include emissions that are within the operational boundaries of the organization that is topic of study. Scope 3 includes indirect emissions caused by the organizations activities. (Matthews, 2008) states that businesses tend to use only the scopes that define direct carbon emissions, which lead to an underestimation of the total carbon production of companies with almost 75%. The indirect emissions originating from the supply chain account for a large part of the carbon emissions.

The direct carbon emissions are defined as the carbon emissions that are produced due to activities performed by company-owned assets. These are summarized into four categories each representing different emissions sources:

- Generation of electricity, heat or steam

The generation of electricity that is produced by generators using combustion engines for propulsion produce carbon emissions during the production of energy. By combustion of coal, natural gas, oil or bio fuels the energy captured in the fuels is transformed into electrical power and causes carbon dioxide as one of the by-products. For the production of heat, for temperature control of buildings and/or processes the combustion of natural gas in heating installations causes carbon emissions. Steam can also be a byproduct that is used in process industry.

- Physical or chemical processing

Industrial processes such as the production of cokes, soda ash, aluminum, ammonia, refining of oil, and production of cement, metals, glass and limestone and many more, all produce carbon emissions. Due to chemical reactions or burning of waste products carbon is emitted as the result of these processes.

- Transportation of materials, waste and employees

The combustion of fuel in engines in all types of vehicles produces carbon emissions. All transportation by using vehicles that are owned directly by the company, such as cars, trucks, vessels, airplanes to transport supplies, waste, employees, finished products, cause carbon emissions.

- Fugitive emissions

Intentional and unintentional releases of carbon emission occurring during production and transportation processes cause emission of carbon into the atmosphere. Examples of this are coal piles, wastewater treatment basins, pits, gas processing facilities etc.

The indirect carbon emissions are defined as the carbon emissions that are produced due to activities performed due to the organization, but not in directly owned assets. The products and services that are purchased to support the activities of the organization are part of the indirect emissions. The transportation of products, materials and employees in vehicles not directly owned by the company, for example in leased vehicles or purchased airplane seats, is also included into this part.

- Production of purchased electricity, heat or steam

The largest part of electricity that is used is being purchased from energy supplying companies. The amount of carbon emissions during the production of this purchased energy needs to be taken into account by the consuming organization in order to establish good insight into the actual footprint of an organization.

- Extraction and production of purchased goods, fuels, materials

The carbon emissions produced during the extraction and production of fuels and other materials is part of the footprint of an organization when these are purchased and imported into the boundaries of the organization.

- Transportation of materials, waste and employees

Similar to the transportation of materials, waste and employees in owned vehicles, also the transportation that takes place in leased, hired or otherwise shared vehicles related to the organizations production of goods and services is part of the carbon footprint of the organization.

- Leased assets, franchises and outsourced activities

The carbon emissions caused by activities that take place outside the boundaries of the organization in order to supply or support the organization also add to the carbon footprint of the organization.

- Waste disposal

The disposal of waste generated in operations or in the production of purchased materials and fuels and the sold products at the end of their life-cycle need to be processed and cause the emission of carbon.

- Usage of products and services by customer
The usage of products and services by the customer sometimes can also produce carbon emissions or require consumption of energy produced causing carbon emissions.

- Electricity related emisisons
Due to the loss of electricity caused by transportation and distribution of electricity, emissions are caused. Since the electricity is not used by any client it needs to be accounted for separately.

2.2 The Water Footprint concept

2.2.1 Definitions of the Water Footprint

Literature study into the definition of the water footprint identified one leading author active in this field. Due to this fact, the amount of definitions for this concept is still limited and does not cause much confusion. Different types of water footprints can be distinguished based on the entity for which it is determined (Gerben-Leenes, 2008). The water footprint of a product is defined as the total volume of fresh water that is used directly or indirectly for the production. It is estimated by considering water use in all steps of the production chain; it is acknowledged that the production stage is not the only part of the productions chain adding to the water footprint. The water footprint of primary crops (m3/ton) can be calculated as the crop water use of a field level (m3/ha) divided by the crop yield (ton/ha). The water footprint of an animal can be estimated based on the water volumes of their food and the volumes of drinking and service water consumed during their lifetime. As input data one needs to know the age of the animal when slaughtered and the diet of the animal during its various life stages. The calculation of the water footprint of livestock products can again be based on product fractions and value fractions. The water footprint of an individual or group of consumers consists of two components: the direct water use, (at home or in the garden) and the indirect water use, (water use in the production and supply chains of goods and services consumed). The indirect water footprint is determined by the water footprints of all products that are consumed by the individual during its lifetime. This can be determined by multiplying all products consumed by their respective product water footprint. The water footprint of a business can also be determined. This consists of the direct or operational water usage and also the total water use in the supply chain. As explained in the first paragraph this water can be separated into three different colors, grey, blue and green. The supply chain aspect of the business water footprint results into shared responsibilities in reducing the water footprint of a business due to the tight coupling between the different links in the supply chain.

The concept of virtual water, introduced by Hoekstra, adds the relevant geographic dimension to the concept of the water footprint. Virtual water is the amount of water contained in an agricultural or industrial product due to its production process (Hoekstra, 2002). For crops that are grown in South-American countries and imported to the Netherlands, the virtual water content consists of all the freshwater that was used before the crops arrived at their destination. The relevance of the water footprint is increased largely by taking into the account the geographic location at which the freshwater usage took place. Even more important is to take into account the level of water scarcity at this location. If the crops are grown in areas in which freshwater is available, the impact of extracting freshwater is far less when compared to extracting the same amount of water in areas in which water scarcity plays an important role. Hoekstra argues that the concept of virtual water can be part of the solution of water scarcity in certain areas (Hoekstra, 2006). If the products are produced in those areas where water is not a scarce resource and exported to areas in which water is a scarce resource, the trading of this virtual water might be part of the solution. Unfortunately the current situation is showing the exact opposite situation in which the already suffering areas export large quantities of virtual water into other regions. This picture shows the flows of virtual water due to the import of agricultural products into the Netherlands from all over the world.

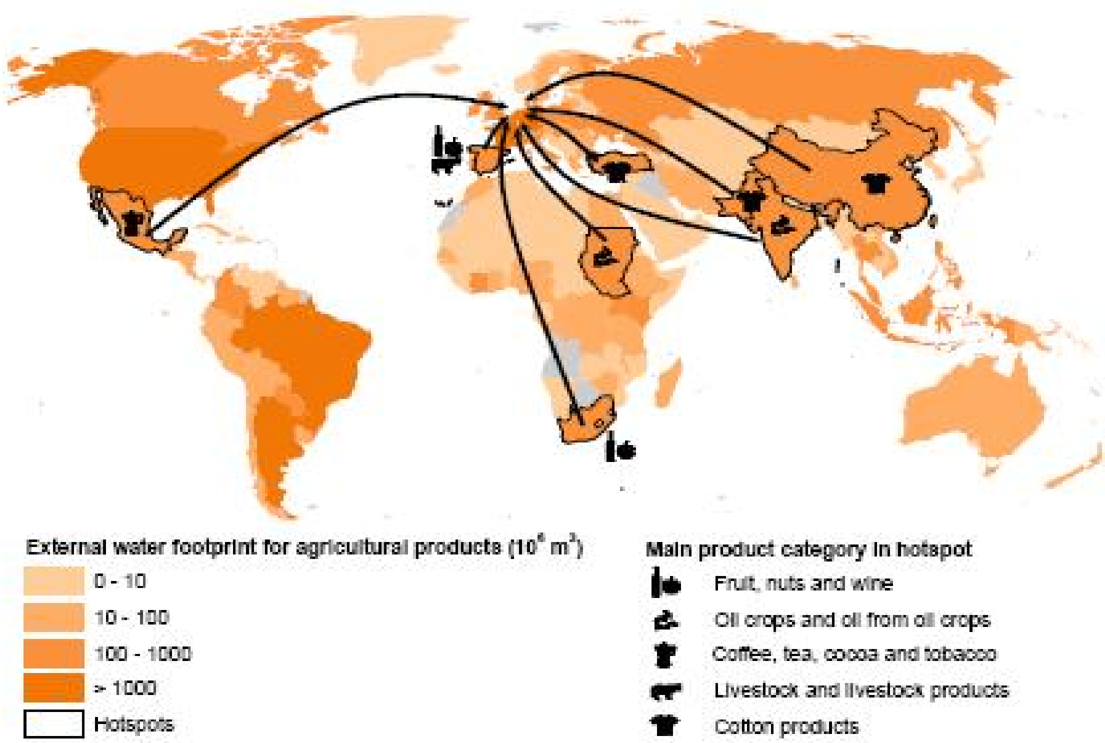


Figure 8 External water footprint for agricultural products of the Netherlands (Hoekstra, 2006)

2.2.2 Methods for determining the water footprint

Different methods are available to determine the water footprint in literature. The bottom-up approach can be found in the approach that Hoekstra proposes. In his article on Water Footprint Business Accounting he introduces a six-step framework for determining the water footprint of a business (Hoekstra, 2008). The first step is to define the business; preferably the business is divided into business units that are situated at one location. The second step is to determine the operational water footprint per business unit. This is done by calculating the blue, green and grey water footprint based on data and measurements at the given location. The third step is to calculate the water footprint of the supply chain of the different business units. Also this water footprint has to determine the three components separately. This allows the total numbers to represent these figures also. The fourth step is to calculate the total water footprint of the business unit by adding up the indirect and direct water footprint. The fifth step estimated the water footprint for every product specific by dividing the business water footprint by the output volume. This allows comparison on product or service level. The sixth and final step aggregates the footprints of the business units into the total business water footprint of the company.

The top down approach, based on the input output analysis developed by Leontief in the 1930's, is also used for determining the water footprint. Zhao described the research to the national water footprint of China in 2002 in his article (Zhao, 2009). This article describes an applied case of the IO-framework to determine the water footprint of China in 2002. This method uses information on monetary transactions between sectors data to account for the complex interdependencies of industries in modern economies. And is based on the amount of water needed to produce a ton of a certain product, and multiplies this with the total amount of imported and exported products of this type.

2.2.3 Standard of the Business Water Footprint

Hoekstra has developed the concept of the business water footprint and published it in 2002 together with Hung (Hoekstra, 2002). He defined the water footprint of a business as the total annual volume of freshwater that is used directly or indirectly to run and support a business.

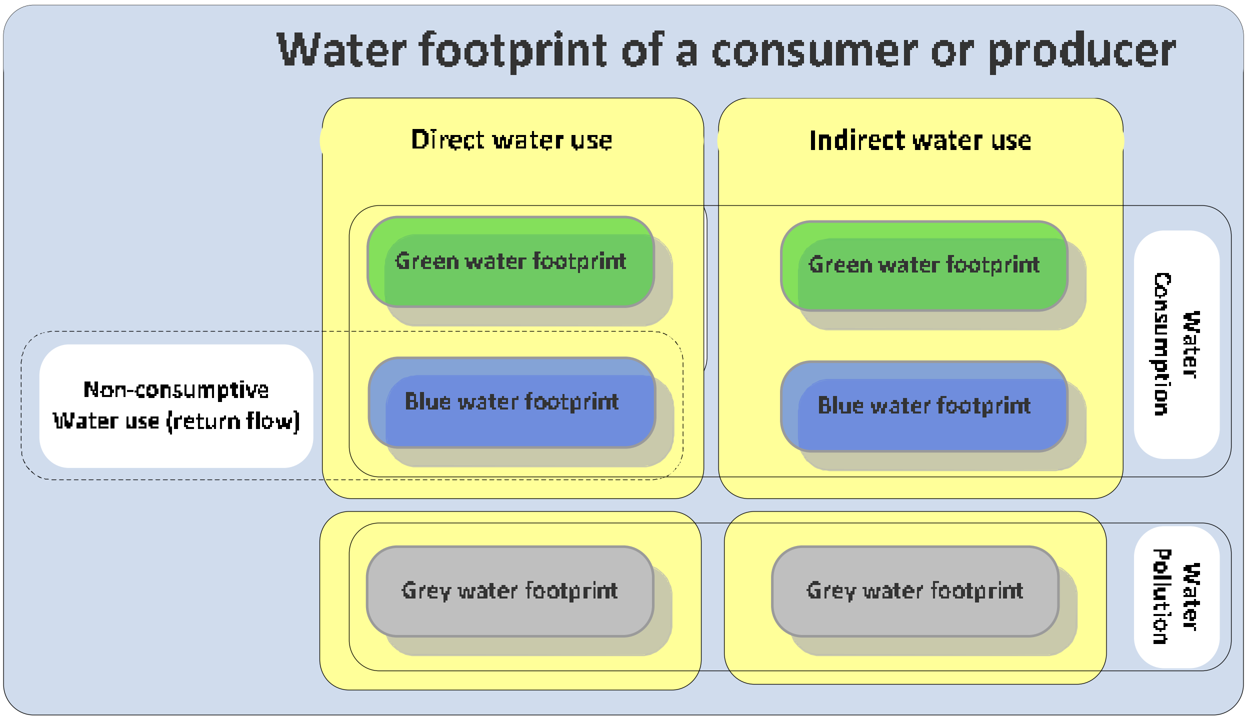


Figure 9 Schematic overview Water Footprint, (based on Hoekstra, 2008)

The water footprint of a business consists of two components: the operational water use (direct water use) and the water use in the supply chain (indirect water use) (Hoekstra, 2008). In addition to this Hoekstra defined three components to determine the total water footprint of a company. The 'green' component is defined as the amount of water that evaporates from the soil during the production process of most agricultural products, and refers to the total rainwater evaporation during crop growth. The 'blue' component of the water footprint refers to the volume of surface and groundwater evaporated as a result of the production of the product or service. The third component is the grey water, which refers to the amount of polluted water that associates with the production of all goods and services of the company; it is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards (Hoekstra, 2008).

The direct water usage is caused by the activities of the organization itself. It is accounted for as direct water use when the organization is extracting freshwater from the soil, ground, surface or municipal supply for supporting the activities of the organization. This can be divided into three types of water:

- Evaporation of freshwater from the soil (Green water)
During the production of agricultural crops, rainwater is extracted from the soil moisture. This water is necessary for growing the crops. During the growth of the crops this water evaporates into the atmosphere and is absorbed into the crop.

- Evaporation of ground and surface water (Blue water)
During the production of crops the amount of water that is necessary for irrigation of the fields is extracted from the ground and surface water, part of this evaporates and does not return in the system from which it came. For industrial products water that is extracted from ground or surface water that does not return into the system is counted as withdrawn for the production.

- Polluted water (Grey water)
Waste water that is associated with the production of goods and services is quantified as the amount of water that is required to dilute pollutants to such an extent that the quality of the ambient water remains above agreed water quality standards.

The indirect water usage of an organization is caused by the water that is necessary for the production and processing of the products before they enter the boundaries of the organization.

- Virtual water content (Blue, Green, Grey)
All products and services that are used as input for the operational processes of the organization contain 'virtual water'. This refers to the amount of water that was used for the production of the products and services that were imported into the boundaries of the company. This part of the water footprint is the indirect water usage that is not directly caused by the organization, but does exist due the activities performed by the organization.

2.3 Intermezzo: Comparison of the maturity of both concepts

The two concepts of the carbon and the water footprints differ in terms of maturity. The carbon footprint has been developed into standardized protocols that describe in detail how to perform a carbon footprint study. Numerous of these studies have been performed and the results are published. The Water Footprint has not yet been developed into the same maturity when compared to the carbon footprint. In this field one main author (Hoekstra) and developer of the Water Footprint Concept is publishing on this topic. Although several conferences are held on both the Water Scarcity and the Water Footprint concept, it is only a few first-mover companies that have performed water footprint studies. Most of these focus on case-studies on product level. A desk research study performed at Ernst & Young Netherlands, which included the annual reports of the 25 largest companies in Europe, has indicated that none of these companies report on their total Water Footprint (Demoulin, 2009). The concepts of the Carbon footprint of an organization has been established and accepted into standards, driven by the Carbon trade market in the EU. The concept of the organizational Water footprint has been developed and published in one article, called Business Water Footprint. No reports of the practical application of this concept are found in literature at this moment. Several case studies that determine the water footprint for individual products, mostly agricultural, that have been performed by Hoekstra and some associate researchers are available. Also the footprints of nations have been calculated, by using the input/output analysis as described in paragraph 3.1 and 3.2. The website www.waterfootprint.org, hosted by the Water Footprint Network, founded by the Scientific Director of this organization, Hoekstra, publishes the latest development in this field of research. Based on this literature study it can be stated that the maturity of both concepts is different. The carbon footprint has been developed much further and although many different and conflicting definitions are available, the organizational carbon footprint was developed into one standard, the Greenhouse Gas Protocol. The water footprint of an organization has not been developed yet; this field is still in development and topic to conferences organized by first-mover organizations.

2.4 Conclusion: available concepts in literature

This chapter started with posing the question:

- What concepts for determining a combined carbon and water footprint of an organization can be derived from literature? -

Based on the results of an extensive literature study this question is answered. Literature provides the GHG protocol for determining the carbon footprint of an organization. This is a concept developed into maturity, widely adopted by both scientists and practiced by organizations. The business water footprint concept is a conceptual model for determining the water footprint of an organization. Although this has not reached maturity and has not been applied into practice yet, it does provide a solid basis for determining the water footprint of an organization. By combining the essential elements of both concepts and adding the crosslinks between the sources of water use and carbon emissions it is expected that a rigor conceptual model for the combined carbon and water footprint can be developed, which is topic of chapter 3.

3 Conceptual model for the combined carbon and water footprint of an organization

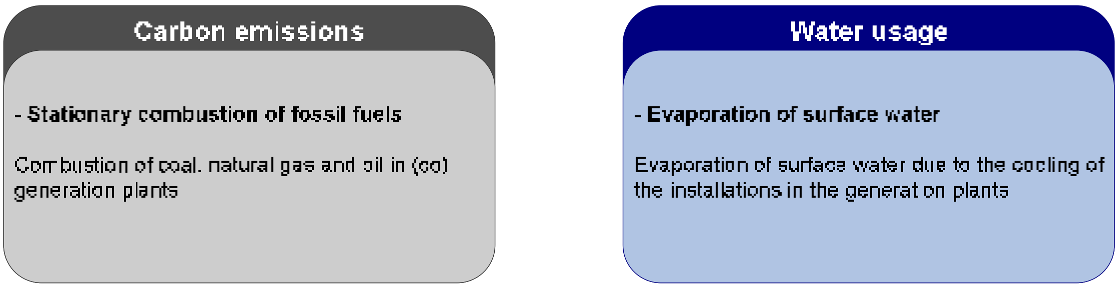
- What conceptual model for the combined carbon and water footprint of an organization can be designed based on the existing concepts? -

The combined carbon and water footprint of an organization is the ecological impact of an organization on its environment, measured in the total amount of carbon emissions and the total freshwater withdrawal. As stated in paragraph 2.1.1, four elements have to be defined when stating a definition of a footprint: the entity that is subject to the study, the sources of the environmental impact and the scope that is taken into account. Based on the combination of the existing concepts of the carbon and water footprint as described in chapter 2, the conceptual model will be developed. This chapter first describes the interrelations between both concepts and then states the developed conceptual model.

3.1 Combining the carbon and water footprint concepts

Chapter 2 describes the concepts of the carbon and water footprint of organizations. These are adopted to form the basis for the conceptual model. The categories as defined in the concept of the business carbon footprint cover all activities causing emissions. The extraction of water takes place due to activities performed by the organization and by direct consumption of freshwater from the different sources. Since the defined categories of activities performed by an organization in the business carbon footprint are covering the total range of activities, this will be used as the basis for developing the conceptual model. To be able to develop a conceptual model of the combined carbon and water footprint of an organization it is necessary to identify the interrelations between the production of carbon emissions and the consumption of water.

3.1.1 Generation of electricity, heat or steam



The production of electricity using the combustion of fossil fuels produces carbon emissions. Different types of power plants use different fuel types to power their generators. Coal, natural gas and oil are the three types of fossil fuels used for the production of electricity in the Netherlands. Also the efficiency of the generators is different. Due to these characteristics the amount of freshwater needed and the amount of carbon emissions emitted differs per kWh of produced electricity. For the production of heat most commonly the combustion of natural gas is used to produce this heat or the heat is produced in cogeneration plants.

3.1.2 Physical or chemical processing

Carbon emissions

- Process emissions

Carbon emisisons due to physical and chemical processes typically found in chemical and heavy manufacturing industry

Water usage

- Evaporation of surface/ground/municipal water

Usage of water as process water, ingredients or cooling water

Physical or chemical processes produce carbon emissions due to chemical reactions. Freshwater is used as process water either for support of the processes or as an ingredient absorbed into the end product. In this category the emissions and the usage of freshwater due to these processes are taken into account. Examples of industrial processes that produce emissions in this category are the production processes of cement, soda ash, ammonia, cokes, iron, oil, gasses, anodes etc.

3.1.3 Transportation of materials, fuels, products and employees in company-owned vehicles

Carbon emissions

- Mobile combustion of fossil fuels

Combustion of fossil fuels in engines in different means of transportation

Water usage

- Evaporation of ground/surface water

During the extraction and production of the fuels process water is used, also for the production of bio-fuels freshwater is used for growing the crops

The transportation taking place in company-owned vehicles often requires the combustion of fossil fuels in mobile assets such as cars, vans, trucks, vessels, airplanes and other motorized means of transport. Transportation might be necessary to transport materials, products, employees or in case of waste-processing companies, waste. Also the use of rail-mounted vehicles such as trains, cranes, trams or other vehicles requires energy for propulsion. Most common is the use of electricity transported by wires, which in most cases is purchased from another organization. Due to the combustion of fossil fuels in transportation means, carbon emissions are emitted.

3.1.4 Leakages

Carbon emissions

- Fugitive emissions

(un)intentional gas releases from pressurized equipment,open-air storage or transportation pipes

Water usage

- Leakage of water

(un)intentional water releases or leakages from storage or transportation equipment

Fugitive emissions occur due to the (un)intentional releases of gasses during processing of gasses. Most common these emissions occur due to industrial activities. This can occur due to leakages in transport lines, open-air storage of fossil fuels, open-mining and usage of pressurized equipment. The leaks of valves, pipe connections, mechanical seals and other related equipments cause emissions or water leakages. Also waste water treatment facilities and storage tanks cause fugitive emissions.

3.1.5 Generation of purchased heat, electricity, steam

Carbon emissions

- Stationary combustion of fossil fuels

Combustion of coal, natural gas and oil in (co) generation plants

Water usage

- Evaporation of surface water

Evaporation of surface water due to the cooling of the installations in the generation plants

All electricity, heat or steam that is purchased by an organization, was generated by another organization. This requires the generation of electricity in a power plant by burning fossil fuels or by generating electricity using durable resources. In the last case no carbon emissions will be produced, but for the combustion of fossil fuels in power plants carbon emissions do occur. To operate a power plant water is also used. Most power plants in the Netherlands make use of cooling towers to regulate the temperature of the installations. During the cooling process large amounts of freshwater evaporates into the atmosphere. The generation of heat can be necessary to increase the temperature of the working environment, most common applied for the heating of buildings such as offices or other facilities. Also some industrial processes require the increase of temperature, for example for boiling, melting or other applications. In most cases this heat is generated by combustion of fossil fuels. For other industrial processes the production of steam is necessary. Steam can be used in process industry due to its ability to transport heat, and is used for many application. For the production of steam water is necessary and mostly also the combustion of fossil fuels.

3.1.6 Extraction and production of purchased materials, goods and products

Carbon emissions

- Carbon emissions purchased materials, goods and products
All emissions related to the purchased materials, goods and products before they enter the boundaries of the organization resulting from the extraction, manufacturing, transportation, storage and processing

Water usage

- Evaporation of freshwater
All water that is evaporated due to the purchased materials, goods and products before they enter the boundaries of the organization resulting from the extraction, manufacturing, transportation, storage and processing

The materials, goods and products that are purchased by the organization to perform its activities are extracted, manufactured, transported, stored and processed before they enter the boundaries of the organization. The production of carbon emissions and the freshwater usage that is necessary for these products to arrive at the organization must be taken into account whilst determining the total combined carbon and water footprint. Different types of products are for example industrial products, agricultural products, chemicals, fuels, raw materials etc. This is represented by the 'virtual' water or carbon content of a product, good or material, representing all carbon emissions and water usage that took place due to its existence.

3.1.7 Transportation of materials, fuels, products and employees in leased or hired vehicles

Carbon emissions

- Mobile combustion of fossil fuels

Combustion of fossil fuels in engines in different means of transportation

Water usage

- Evaporation of ground/surface water

During the extraction and production of the fuels process water is used. also for the production of bio-fuels freshwater is used for growing the crops

Transportation services are not always performed with company-owned assets. Business related travel of employees using airplanes, leased vehicles or public transportation is transportation that takes place to support the activities of the organization.

3.1.8 Electricity related

Carbon emissions

- Stationary combustion of fossil fuels

Combustion of coal. natural gas and oil in (co) generation plants

Water usage

- Evaporation of surface water

Evaporation of surface water due to the cooling of the installations in the generation plants

For the production of electricity that is purchased into the boundaries of the organization, the indirect emissions for the extraction and production of the fossil fuels that are combusted to produce energy in the generation plants can also be taken into account.

3.1.9 Leased assets / franchises / outsourced activities

Carbon emissions

- Carbon emissions

Combustion of fossil fuels. electricity usage. physical or chemical processes occuring due to the leasing. franchising or outsourcing of activities

Water usage

- Evaporation of freshwater

Evaporation of freshwater due to the leasing. franchising or outsourcing of activities

Organizations make use of assets and activities that are not directly owned or performed by employees of the organization. Leasing and outsourcing is common practice to have supporting activities performed by third parties. Many assets such as buildings, facilities, terminals etc. are not directly owned by the organization but are leased or otherwise rented for performing activities in favor of the organization. Administrative tasks such as financial administration, consulting activities, pension funds, banking activities, production in cheap-labor countries are all examples of typical activities being outsourced to third parties. The carbon emission and water usage due to the usage of these activities in favor of the organization must be taken into account whilst determining the combined carbon and water footprint of the organization.

3.1.10 Use of sold products and services

Carbon emissions

- Carbon emissions

Combustion of fossil fuels, electricity usage, physical or chemical processes occuring due to the leasing, franchising or outsourcing of activities

Water usage

- Evaporation of freshwater

Evaporation of freshwater due to the leasing, franchising or outsourcing of activities

After the products and services leave the organization the usage of the products can also require freshwater or cause carbon emissions due to usage of fossil fuels or electricity during the use phase. Examples are all electrical equipment, transportation vehicles and consumer goods. For the usage of these products it can be necessary to use electricity or fossil fuels that result into emissions. Also the use phase can require freshwater for further processing of the products.

3.1.11 Waste disposal

Carbon emissions

- Waste incineration

The combustion of waste in incineration facilities results in carbon emisisons, the recycling processes can involve electricity usage or combustsion of fossil fuels

Water usage

- Evaporation of freshwater

Evaporation of freshwater occurs due to the processes necessary for the recycling of waste

All the waste that is produced due to the activities of the organization must be processed, this can be recycled, reused or combusted. The incineration of garbage in large waste processing facilities causes carbon emissions. Since the production of waste is the responsibility of the organization these emissions need to be taken into account when determining the carbon footprint of the organization.

3.1.12 Consumptive water usage

Carbon emissions

- Electricity requred for water purification
Electricity consumption for powering the purification installations

Water usage

- Water withdrawal from ground/surface water

Withdrawal from freshwater for purification

Freshwater extraction from ground, surface and municipal supply due to the consumptive use is taken into account in this category. This category is concerned with all extraction of freshwater that is not directly related to a process or activity in the core of the organization. Extraction of water by employees for drinking, washing, cleaning, reducing dust hindrance and all other activities that is not returned into its original source is accounted for in this category.

3.2 The entity of the combined carbon and water footprint

The entity, which is the subject of study, for the combined carbon and water footprint is 'an organization'. The adopted definition of an organization is 'a coherent entity producing goods and/or services that are supplied to consumers or other businesses (Hoekstra, 2008). In order to assess the organization, it must be clearly delineated from its environment. To be able to assess any type of organization it is necessary to adopt a broad definition that is applicable to any type of organization. To be able to delineate the organization from its environment it is visualized as a basic organizational structure which represents the basic element of an organization.

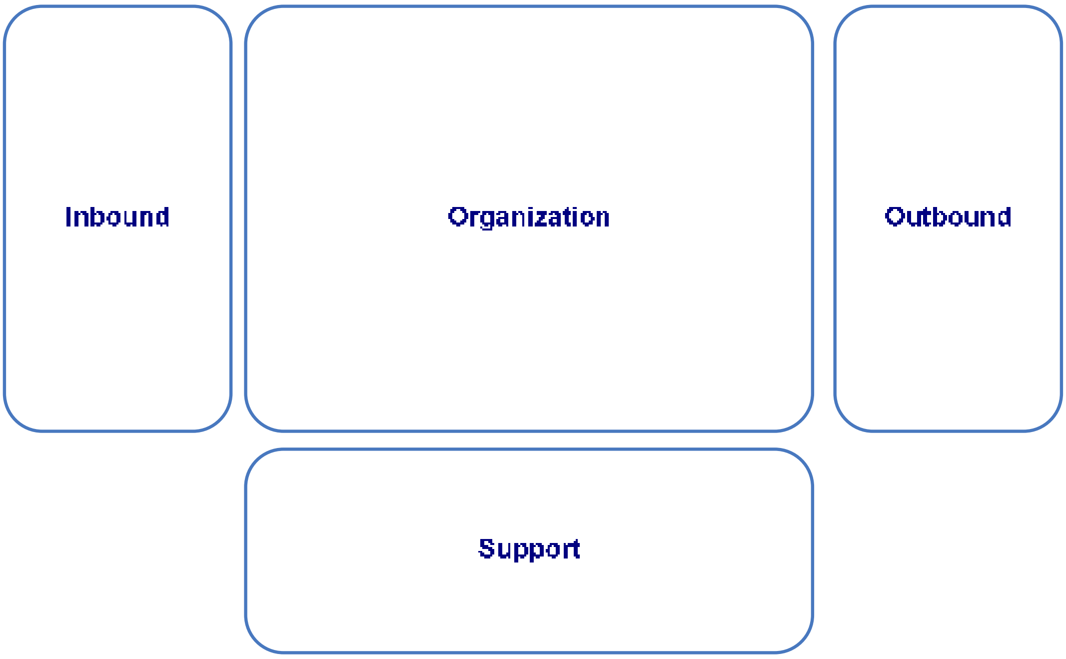


Figure 10 Basic structure of an organization

The distinction between the different elements of the organization is made based on ownership. The center is the organization itself, including all assets owned by the organization. The left block represents the inbound part of the organization including all products and services that are entering the boundaries of the organization. The outbound part of the organization includes all products, services leaving the organization and the disposal of waste. The support block includes all assets used by the organization but not owned; also the activities performed in favor of the organization that are outsourced to other entities are included in this element. Together these four elements determine the entity which is subject of the study in the combined carbon and water footprint of an organization.

3.3 The scope of the combined carbon and water footprint

The scope that is taken into account in the combined carbon and water footprint is based on the scopes as are taken into account in the existing concepts. The GHG defines 3 scopes in which carbon emissions can be accounted for. The Business water Footprint defines the direct or operational water footprint and the indirect or supply chain water footprint. The conceptual model of the combined carbon and water footprint integrates both scopes. The organization element contains all direct emissions and freshwater usage of the organization, thereby covering Scope 1 of the GHG and the direct water footprint. The inbound and outbound elements take into account the indirect or supply chain water footprint and parts of scope 2 and 3 of the GHG. The support element takes into account the other part of the indirect water footprint and scope 3 of the GHG.

3.4 The sources included in the combined carbon and water footprint

The sources that are included in the combined carbon and water footprint must represent all sources of carbon emission and water consumption of an organization. By adopting the concepts of the GHG and the Business Water Footprint as basis for the combined carbon and water footprint, all sources as defined in these concepts are taken into account. Also the identified crosslinks are adopted into the concept. The sources are discussed, ordered by the part of the organization in which they exist.

Within the boundaries of the organization itself, 5 sources are identified. The production of electricity, heat or steam concerns the carbon emissions due to the combustion of fossil fuels due to stationary combustion in installations, and the evaporation of freshwater due to cooling processes. The transportation of materials, products, fuels and employees is concerned with the carbon emissions due to combustion of fossil fuels in stationary equipment and with the freshwater needed to produce the fuels that are used. The physical or chemical processing and production block accounts for the emissions occurring due to chemical reactions and the freshwater evaporation due to the usage of it as process-, cooling, or ingredient water. The fugitive emissions represents the emissions due to leakages in pressurized equipments, open air storages etc. The fifth block is the extraction of water from the municipal supply or the consumptive water use. The inbound element contains the carbon emissions and freshwater usage due to the production of purchased electricity, heat or steam. The carbon emissions and water usage due to the extraction and production of purchased materials, fuels and products that are purchased into the organization are represented in the element with similar title. The outbound element includes the carbon emissions and water consumption during the use-phase of the products or services which are leaving the boundaries of the organization. The carbon emissions due to the disposal of waste consider the emission due to the processing of the waste that is produced by the organization. The support element contains the carbon emissions and freshwater usage of the activities taking place with leased or hired assets or transportation means.

By taking into account these sources, the concept takes into account all relevant sources as defined in the existing concepts in literature of the carbon and water footprints.

3.5 Conclusion: The conceptual model of the combined carbon and water footprint of organizations

By combining the chosen scope, sources and entity the conceptual model of the combined carbon and water footprint is constructed and represented in the figure below.

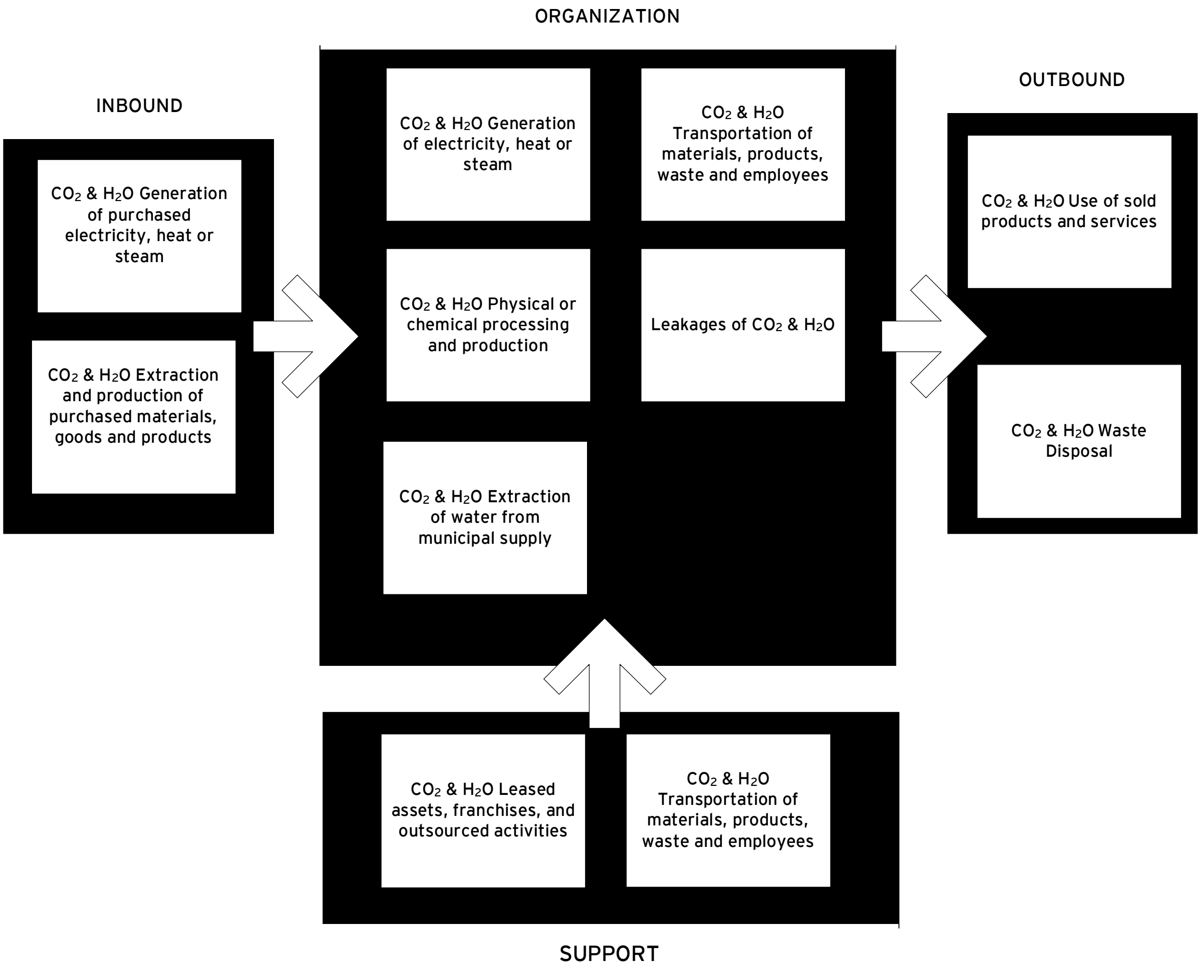


Figure 11 Conceptual model of the combined carbon and water footprint

3.6 The geographical component of the water footprint

The previous paragraphs have defined the conceptual model. One important aspect of the water footprint has not been discussed in it explicitly. The impact of the evaporation of water depends on the geographical location at which this takes place. Evaporating 1.000m^3 of freshwater in Ghana has a total different meaning than doing this in the Netherlands. For interpreting the values determined in a water footprint study insight into this geographical location is essential. Figure 12 shows the water scarcity index map as published by the Grid- Arendal. This is an official United Nations Environment Program collaborating centre, supporting informed decision making and awareness-raising trough their research and publications.

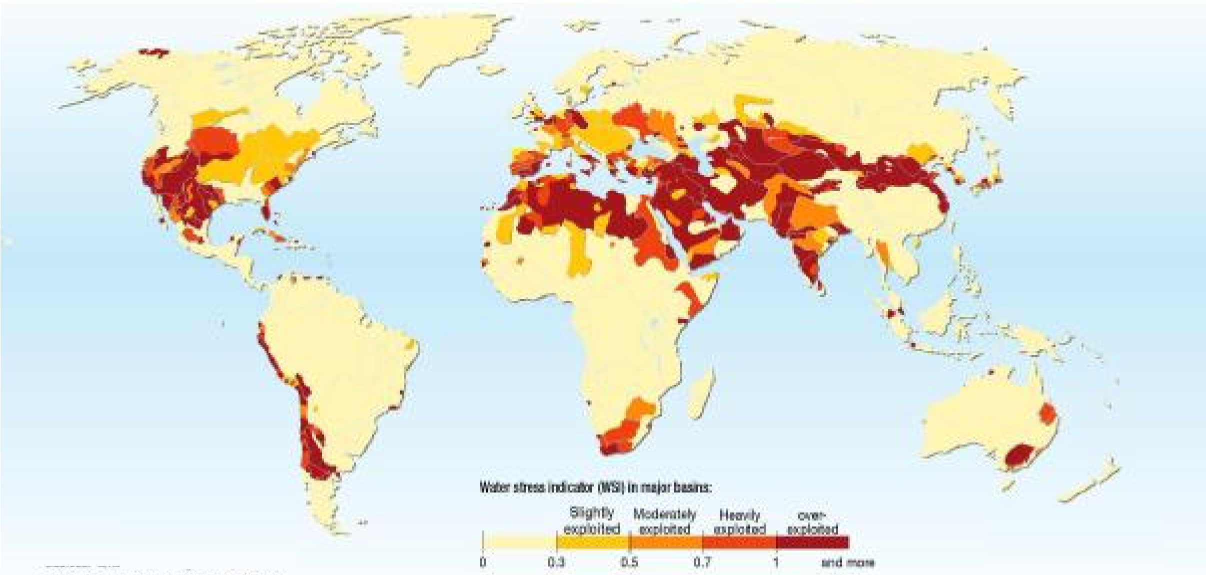
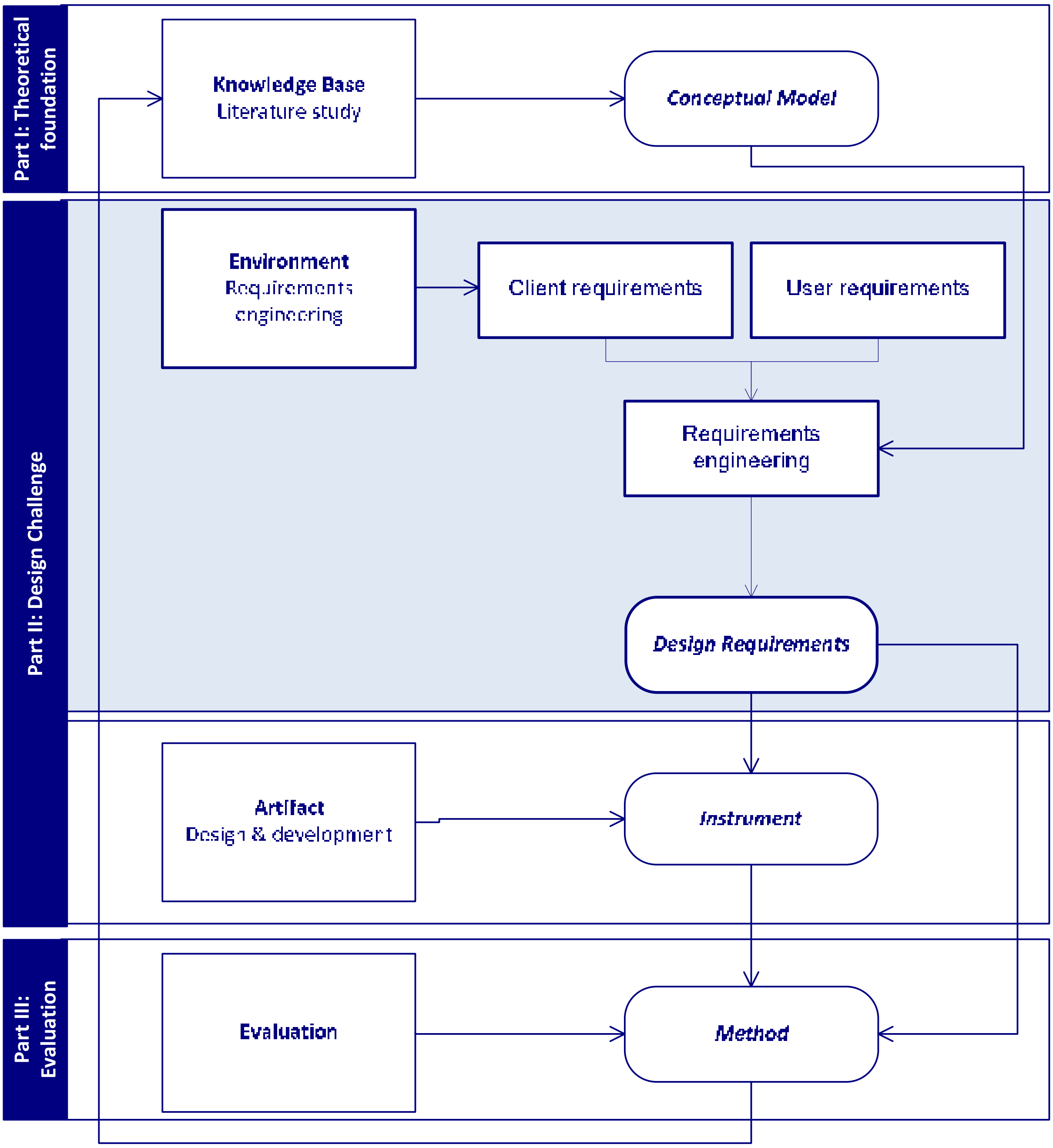


Figure 12 Water scarcity index (UNEP/GRID, 2009)

The water scarcity map as shown in Figure 12 represents the water scarcity index of geographical areas. The number on the scale from 0-1 and beyond is determined based on the ratio between the total extraction of water and the amount of sustainable available water. For organizations the indirect or supply-chain part of the water footprint mainly causes the geographical related impact. In case the organization has production location in these areas these activities also concern this. At this point in time information on the supply-chain component is made available by (Hoekstra & Chapagain, 2008) for agricultural products for a large number of countries. By mapping the geographical locations of the extraction points of freshwater and combining these with the water scarcity levels, this gives insight into the total impact of the water footprint of the organization.

The interpretation of the water footprint can not be done without taking this element into account. Disadvantage of this is the high level of detail that is required to be able to make location based calculations. However this field of knowledge is rapidly developing and producing publications regarding the geographical element of the water footprint. Therefore it is expected that it will be possible to quantify this component in the near future.

Part II:



Part II: Design challenge: an instrument for E&Y based on the conceptual model

Chapter 4: What are the requirements for the instrument that is able to calculate the combined carbon and water footprint of an organization?

Chapter 5: What instrument can be developed that is able to calculate the combined carbon and water footprint of an organization?

4 Design requirements

- What are the requirements for an instrument that is able to calculate the combined carbon and water footprint of an organization? -

The practical objective of this research is to design an instrument that is able to assist organizations in gaining insight into the combined carbon and water footprint, as stated in paragraph 1.2. Having defined the conceptual model for the combined carbon and water footprint in chapter 3 the design challenge is to translate this conceptual model into a practical applicable artifact that fulfills the demands of the user.

The future user of the instrument will be Ernst & Young Business Advisory Services. The instrument will be applied to determine the combined carbon and water footprint of an organization. The setting in which the instrument will be applied is within client-advisor relationship. The instrument will be used to assist the advisor in fulfilling the information need that is present at the client.

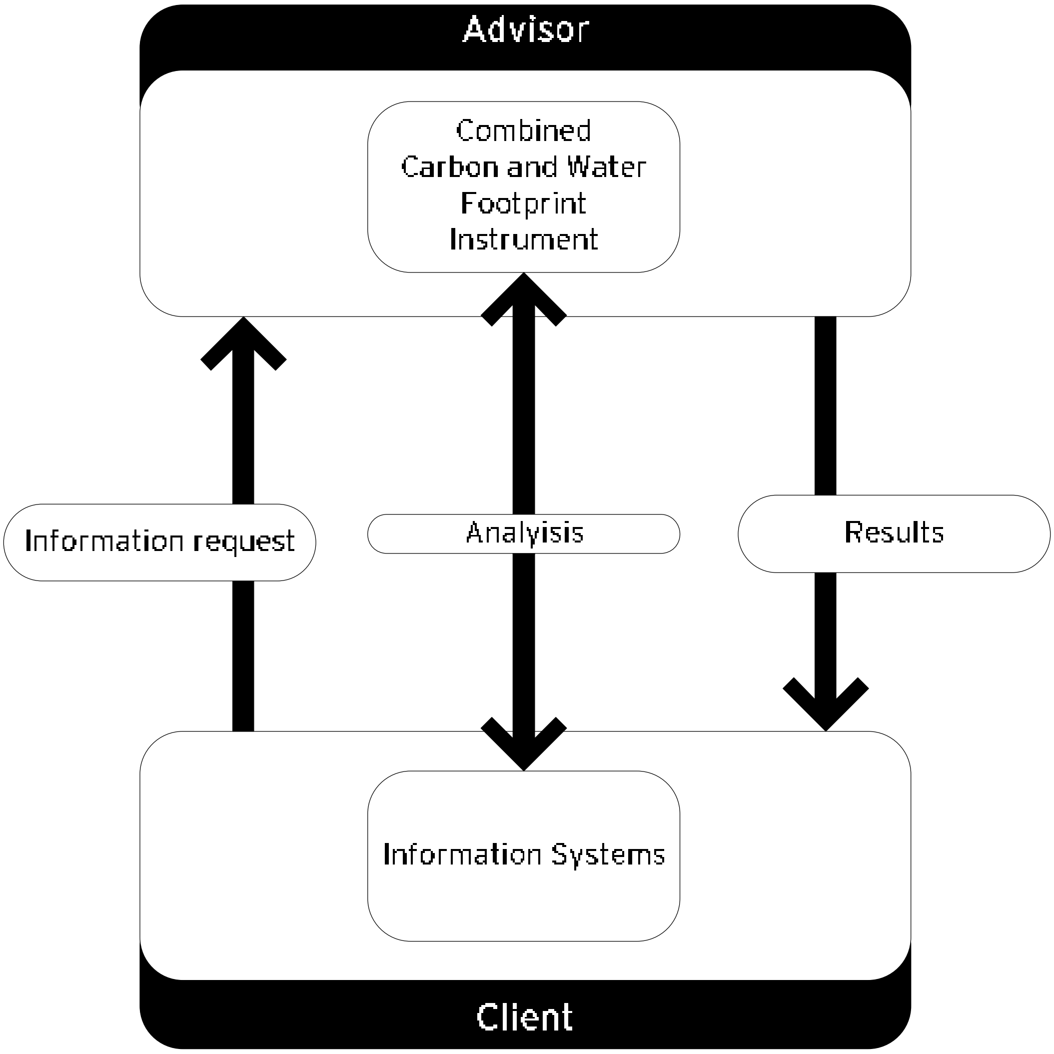


Figure 13 Interaction between advisor - client and the instrument

The advisor is an employee at Ernst & Young Business Advisory Services with an academic background and limited working experience. The situation as presented in Figure 13 represents the working field in which the instrument will be applied in the future. The client is interested in determining the combined carbon and water footprint and phrased the question towards the advisor to assist him in this process. This could for example be the CEO of a large multinational firm as stated in the introduction of this report. In order to be successful in assisting the process of fulfilling the information demand that is present at the client, the instrument must fulfill the demands of both the advisor and the client. The need for information must be fulfilled by making use of all available knowledge in the organization. Information systems that are present in the organization will form important sources for information. The instrument plays an important part in the interaction between both parties and is responsible for supporting the entire process of information gathering, calculating, producing output in order to support the process of advising. Next the requirements of both the future users (advisors) and the clients (organizations) are stated. This results in the total set of requirements in paragraph 4.3.

4.1 Client requirements

The information need that is present at organizations forms the basis for developing a practical applicable instrument. It is important to gain insight into the exact needs and demands of customers and take this into account during the development of the instrument.

4.1.1 Goal

The goal of developing the client requirements is to gain better insight into the exact demands that are present to the instrument. Establishing a full Combined Carbon and Water Footprint study is expected to be a labor intensive process. Since organization face the reality of the limited availability of resources it is important to establish insight into the exact demands and limitations that are present within organizations.

4.1.2 Approach

Finding the requirements of the future clients (organizations) is done by interviewing an expert in the field of sustainability related advisory, Dietmar Laske, executive senior-manager at Ernst & Young Business Risk Services. Due to his large experience in consulting work in the field of sustainability related issues at large organizations he was the preferred expert to perform this interview with. After several conversations the main findings have resulted in stating the requirements.

4.1.3 Results

Main interest of future clients lies in the credibility of the instrument, the ease of application, the results must be fit-for-reporting, and have to provide insight into the main causes of the footprint.

The instrument must produce results that have credibility and acceptance for publication
The results of the research must be determined by accepted standards
The instrument must produce results that are valid

The instrument must be applicable with the least possible effort
The instrument must make use of available information from the organization
The instrument must reduce the amount of company specific information needed as input

The instrument must produce outcomes that are fit for reporting
The output of the instrument must have an attractive lay-out

The results of the research must be reported using accepted indicators

The instrument must identify the main causes for the size of the total footprint
The instrument must determine the size of the total combined carbon and water footprint
The instrument must determine the relative size of the different causes

4.2 User requirements

4.2.1 Goal

For this research the requirements to the instrument are established with the main focus on the future user of the artifact which is Ernst & Young Business Advisory Services. The goal is to develop a set of requirements that fully describes the demanded functionalities of the instrument. This set of requirements will be used in the evaluation of the instrument to determine if the requirements are met.

4.2.2 Approach

Requirements engineering is the process of carefully identifying and documenting the needs of the systems' future users (van Vliet, 2001). Various methods are available to conduct a thorough requirements analysis, depending on the type of research. As referred to by the fourth guideline of Hevner (paragraph 1.3), adopting well established methods adds rigor to the research. This is relevant for the phase of establishing the requirements since the requirements form an essential element of the design process and also provide the basis for the evaluation framework.

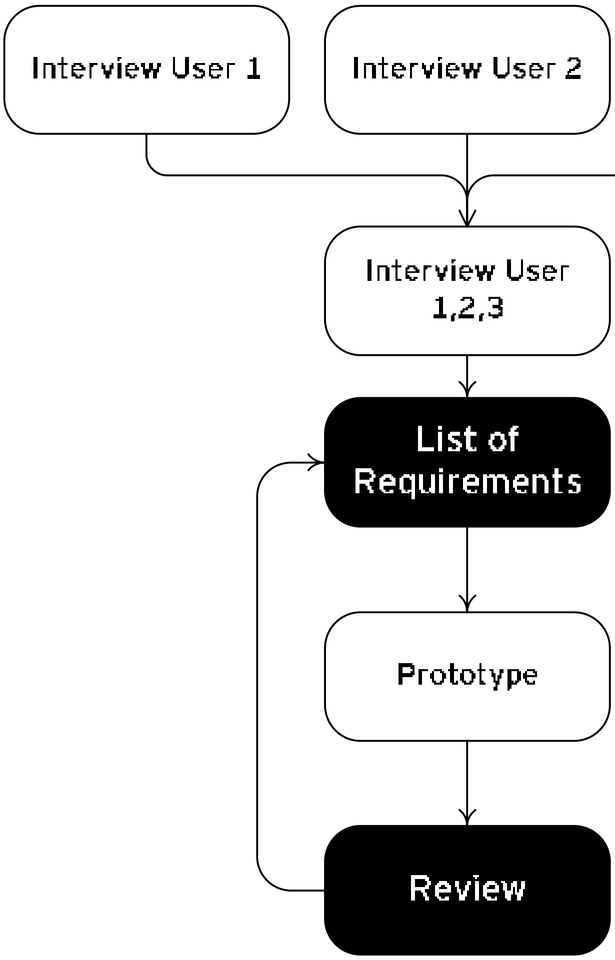


Figure 14 Process of requirements analysis: combined interviews and prototyping

A combination of the traditional approach of interviewing and the exploratory approach of prototyping (Nuseibeh, 2000) is used to obtain the requirements for the instrument. The requirements engineering phase of this research is conducted in close interaction with the future user of the system. Since little experience exists in this field of research, it is hard for both the user and for us to define upfront what the requirements will be. Therefore this combination of interviews and prototyping is used to develop the requirements for the instrument in close interaction with the future user.

Interviews are appropriate methods to ask directly for requirements, allowing the user to define exactly what he needs. Weakness of interviews h in the case of an exploratory research is that the user does not explicitly know what he wants since the knowledge is not yet available (van Vliet, 2001). That is why the interviews are combined with prototyping. Prototyping supports the further development of both the knowledge of the system and its requirements. (van Vliet, 2001). By performing several rounds of interviews and prototyping, the requirements are incrementally developed.

4.2.3 Results

The start of the process was to interview three experts representing the user, in this case senior staff members of Ernst & Young with various fields of expertise. The main goal of these interviews was to identify the first ideas that were present. By combining the results of these interviews and verifying them in a group meeting, the initial requirements for the instrument were established.

- The instrument must be able to determine the combined carbon and water footprint of an organization.
- The instrument must be able to identify the main drivers of the organizations' footprint.
- The instrument must produce output that can be compared to other organizations.
- Applying the instrument must cost as little effort as possible.

Based on the conceptual model of the combined carbon and water footprint as proposed in chapter 2 and these initial requirements, a prototype was developed which formed the first round of the prototyping. Each round the requirements were adapted and improved until the final set of requirements was established. The next paragraph describes the requirements as were developed during this process.

4.3 Conclusion: the requirements to the combined carbon and water footprint instrument

This paragraph concludes the requirement analysis by stating the requirements for the instrument that will support Ernst & Young in determining the combined carbon and water footprint of an organization. The requirements have been established in close interaction with the user, as described in paragraph 3.2. To categorize the requirements the structure as proposed bij (van Vliet, 1999) is adopted. This distinguishes functional and non-functional requirements. The functional requirements are concerned with fundamental functions of the system or 'must-haves'. The non-functional requirements are concerned with the (negotiable) constraints and with the quality requirements or 'soft goals'.

4.3.1 Functional requirements

The instrument must be able to determine the combined carbon and water footprint of an organization.

A.1 The instrument must be generally applicable to any type of organization
A.2 The instrument must adopt the conceptual model
A.3 The instrument must produce valid results

The instrument must be able to identify the main drivers of the organizations' footprint.

A.4 The instrument must be able to identify the most relevant factors causing the size of the footprint.
A.5 The instrument must be able to determine the absolute and relative impact of these factors on the total size of the footprint.

The instrument must produce output that can be compared to other organizations.

A.6 The instrument must calculate the full footprint as defined in the conceptual model
A.7 The instrument must produce output in a format that enables comparison of results with peers

4.3.2 Non-functional requirements

Constraints

Applying the instrument is constrained by a limited budget.

B.1 The duration of applying the instrument must not exceed a total of 30 man-hours.
B.2 The instrument must make use of organization specific information that is readily available in its information systems.
B.3 The instrument must make use of general applicable information from trusted sources.
B.4. The instrument must make use of available hard- and software at Ernst&Young

The instrument must be usable by a person with limited expertise of footprint studies.

B.5 The instrument must be self-explanatory to the user
B.6 The instrument must be well-documented to support the application
B.7 The instrument must be easily maintainable to keep information up-to-date

Quality requirements

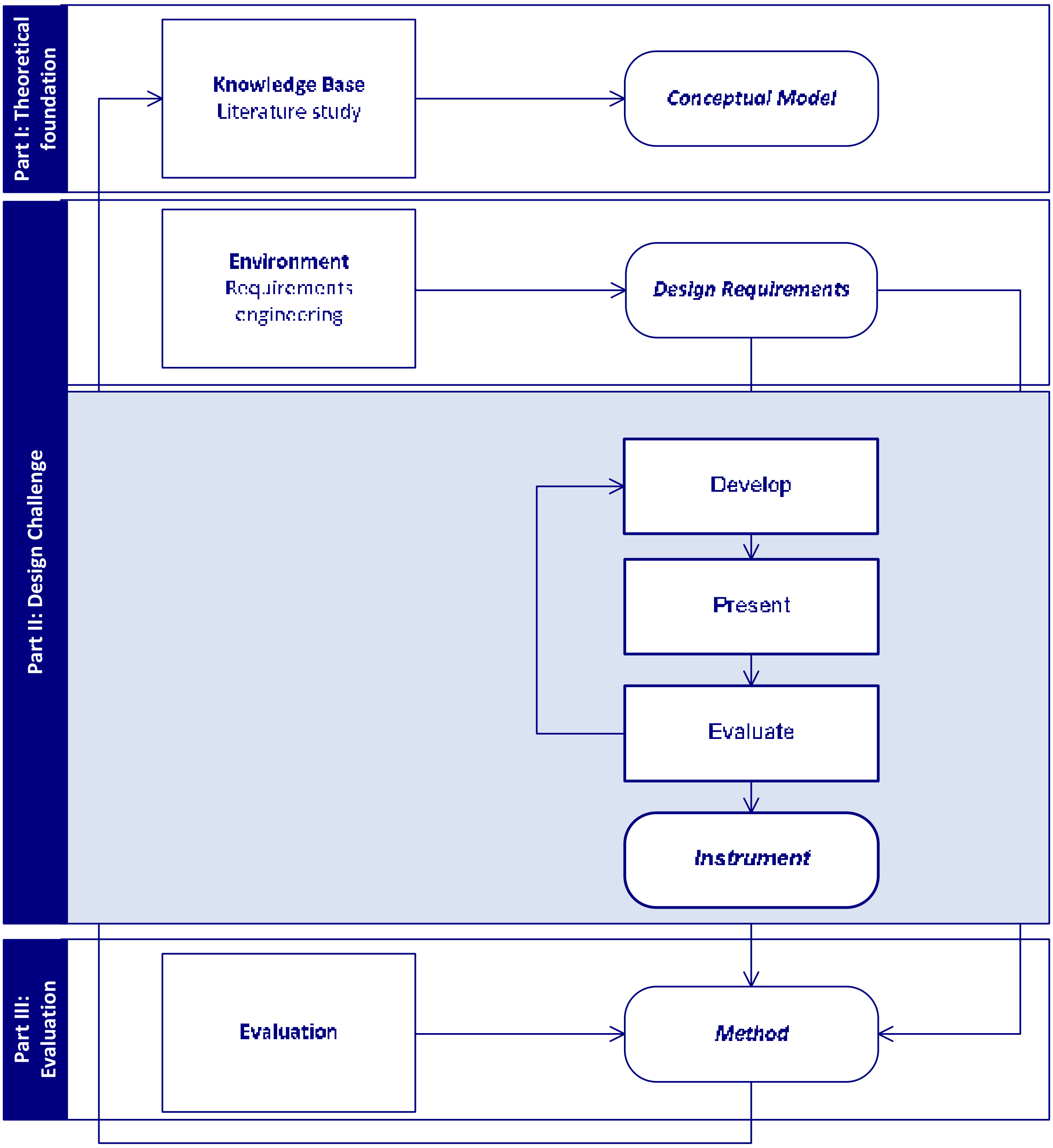
The instrument must produce well interpretable output

C.1. The output must support the analysis of the results
C.2. The output must be fit for reporting
C.3. The output must be interpretable for non-experts

The instrument must produce outcomes that are fit for reporting

C.4. The output of the instrument must have an attractive lay-out
C.5. The output of the instrument must include accepted indicators

Part II:



Part II: Design challenge: an instrument for E&Y based on the conceptual model

Chapter 4: What are the requirements for the instrument that is able to calculate the combined carbon and water footprint of an organization?

Chapter 5: What instrument can be developed that is able to calculate the combined carbon and water footprint of an organization?

5 Functional design

- What instrument can be designed that is able to calculate the combined carbon and water footprint of an organization? -

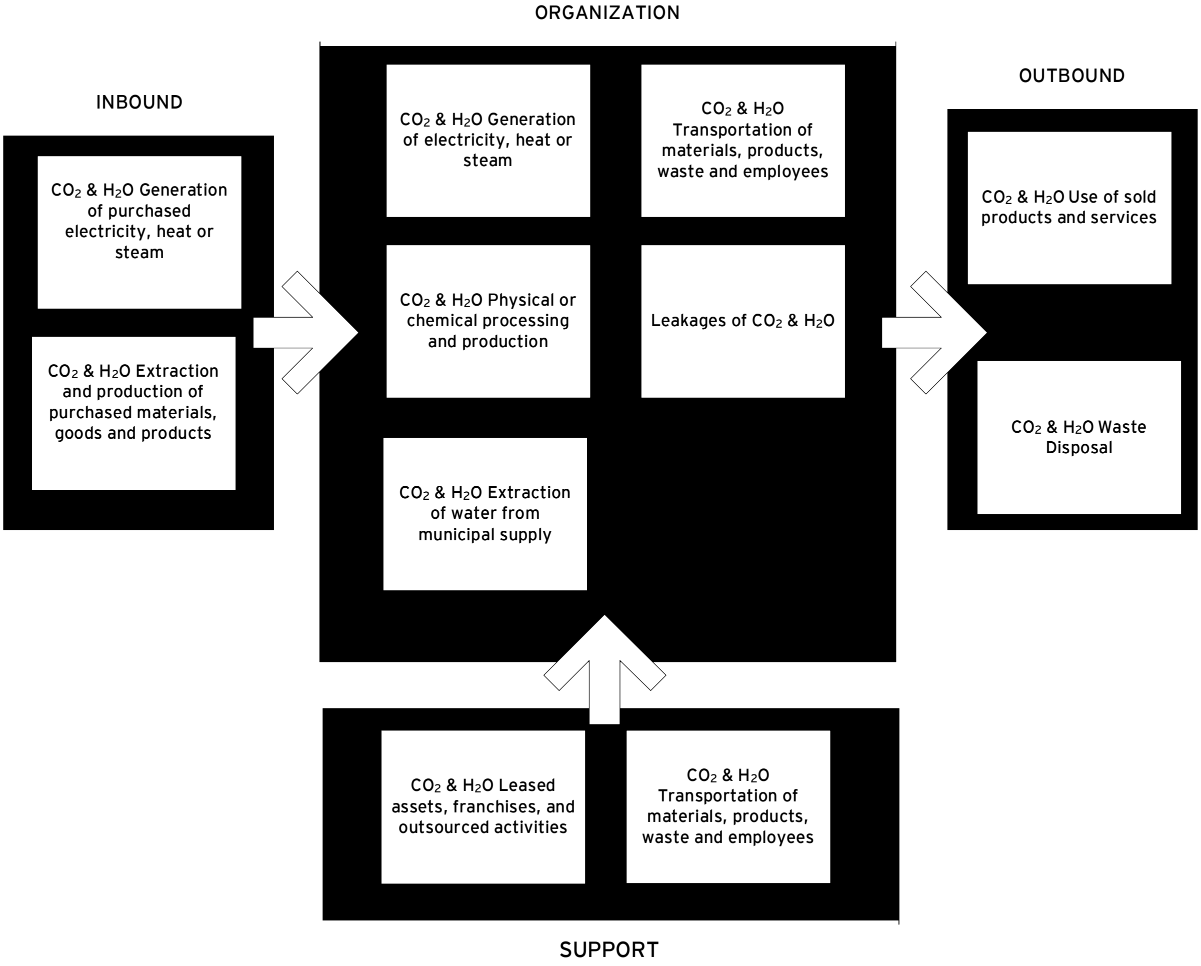


Figure 15 Conceptual model of the Combined Carbon and Water Footprint of an organization

This chapter describes the instrument as it was implemented into a spreadsheet program, based on the conceptual model as defined in chapter 3. This list indicates what elements of the instrument are discussed in what paragraph.

5.1: I.1: Generation of purchased electricity, heat or steam
5.2: I.2: Extraction and production of purchased materials, fuels and products
5.3: Or.1: Generation of electricity, heat or steam
5.4: Or.2: Transportation of materials, products, waste and employees
5.5: Or.3: Physical or chemical processing and production
5.6: Or.4: Leakages
5.7: Or.5: Extraction of water from municipal supply
5.8: Su.1: Leased assets, franchises and outsourced activities
5.9: Su.2: Transportation of materials, products, waste and employees
5.10: Ou.1: Use of sold products and services
5.11: Ou.2: Waste Disposal

5.1: Generation of purchased electricity, heat or steam

5.2: Extraction and production of purchased materials, fuels and products

5.3: Generation of electricity, heat or steam

5.4: Transportation of materials, products, waste and employees

5.5: Physical or chemical processing and production

5.6: Leakages

5.7: Extraction of water from municipal supply

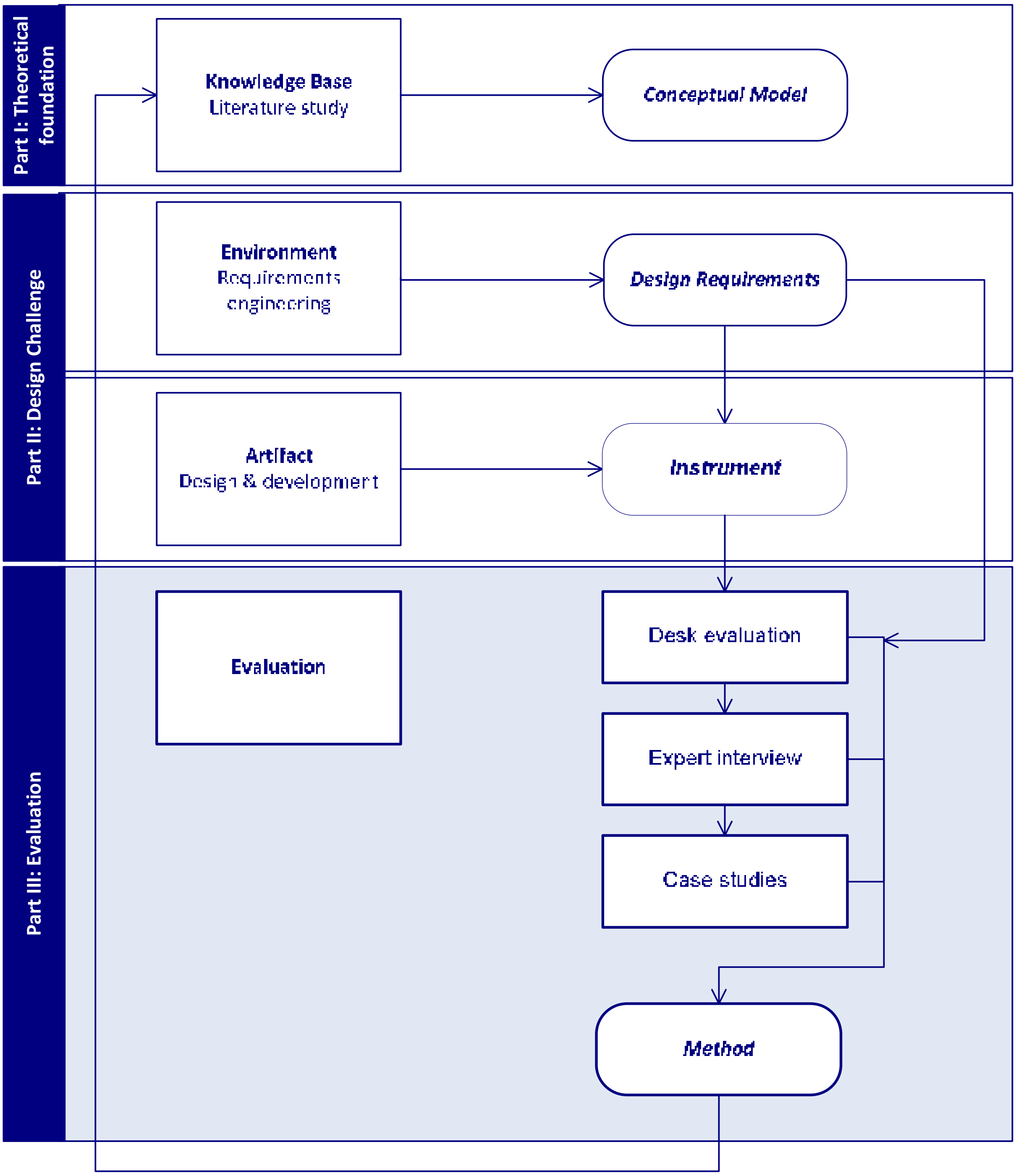
5.8: Leased assets, franchises and outsourced activities

5.9: Transportation of materials, products, waste and employees

5.10: Use of sold products and services

5.11: Waste Disposal

Part III:



Part III: Evaluation: performance of the instrument

Chapter 6: To what extend is the prototype successful in determining the combined carbon and water footprint of an organization with respect to the requirements?

Chapter 7: What guidelines can be stated for application of the instrument?

6 Evaluation

- To what extend is the instrument successful in determining the combined carbon and water footprint of an organization with respect to the requirements? -

Several tests are conducted to determine to what extend the developed instrument is able to fulfill the requirements. The framework of requirements (paragraph 4.3) forms the basis for evaluating the design.

	Functional requirements
	Fundamental functions of the system
	The instrument must be able to determine the combined carbon and water footprint of an organization.
Expert interview	A.1 The instrument must be generally applicable to any type of organization
Desk-test	A.2 The instrument must adopt the conceptual model
Expert interview	A.3 The instrument must produce valid results
	The instrument must be able to identify the main drivers of the organizations' footprint.
Case study	A.4 The instrument must identify the most relevant factors causing the size of the footprint
Case study	A.5 The instrument must determine the absolute and relative impact of these factors on the total size of the footprint
	The instrument must produce output that can be compared to other organizations.
Case study	A.6 The instrument must calculate the full footprint as defined in the conceptual model
Case study	A.7 The instrument must produce output in a format that enables comparison of results with peers
	Non-functional requirements
	Constraints
	Applying the instrument should be possible within limited time
Case study	B.1 The duration of applying the instrument should not exceed 30 man-hours.
Case study	B.2 The instrument should make use of organization specific information that is readily available in its information systems
Desk	B.3 The instrument should make use of general applicable information from trusted sources
Case study	B.4. The instrument should make use of available hard- and software at Ernst&Young
	The instrument must be usable by a person with limited expertise of footprint studies.
Usability test	B.5 The instrument should be self-explanatory to the user
Usability test	B.6 The instrument should be well-documented to support the application
Usability test	B.7 The instrument should be easily maintainable to keep information up-to-date
	Quality requirements
	The instrument must produce well interpretable output
Usability test	C.1. The output could support the analysis of the results
Usability test	C.2. The output could be fit for reporting
Usability test	C.3. The output could be interpretable for non-experts
	The instrument must produce outcomes that are fit for reporting
Desk	C.4. The output of the instrument could have an attractive lay-out
Desk	C.5. The output of the instrument could include accepted indicators

For the evaluation four different methods are applied to check all requirements. An interview with an expert in the field of ecological modeling was performed to check the requirements on general applicability and validity of the instrument. Two case studies were performed to test the instruments capabilities completely. It was used to calculate the carbon and water footprint of two large organizations, which allows the evaluation of the application of the instrument, the usefulness of its results and its capability to operate within the constraints. A usability test was performed with a representative future user of the instrument. A fictive case was performed to be able to evaluate the usability of the instrument for its future user. Also desk tests have been performed to check the requirements which could be internally evaluated on.

The results of the evaluation are presented in this chapter per requirement. The conclusion of the evaluation is stated in paragraph 6.4.

6.1 Functional requirements: must haves

6.1.1 A.1: General applicability

If the instrument can calculate the combined carbon and water footprint of organizations from all sectors, it is generally applicable. The Central Bureau for Statistics published the Standard Categorization of Organizations. This divides all types of organization into 18 sectors. If the instrument is applicable to all those sectors it is stated being generally applicable. Due to time constraints this could not be tested during this research by applying the instrument to all sectors. Instead an expert judgment is used to estimate the application domain. Figure 16 shows the results of the interview: the expert judgment. The full report of the interview is included in

Appendix A.

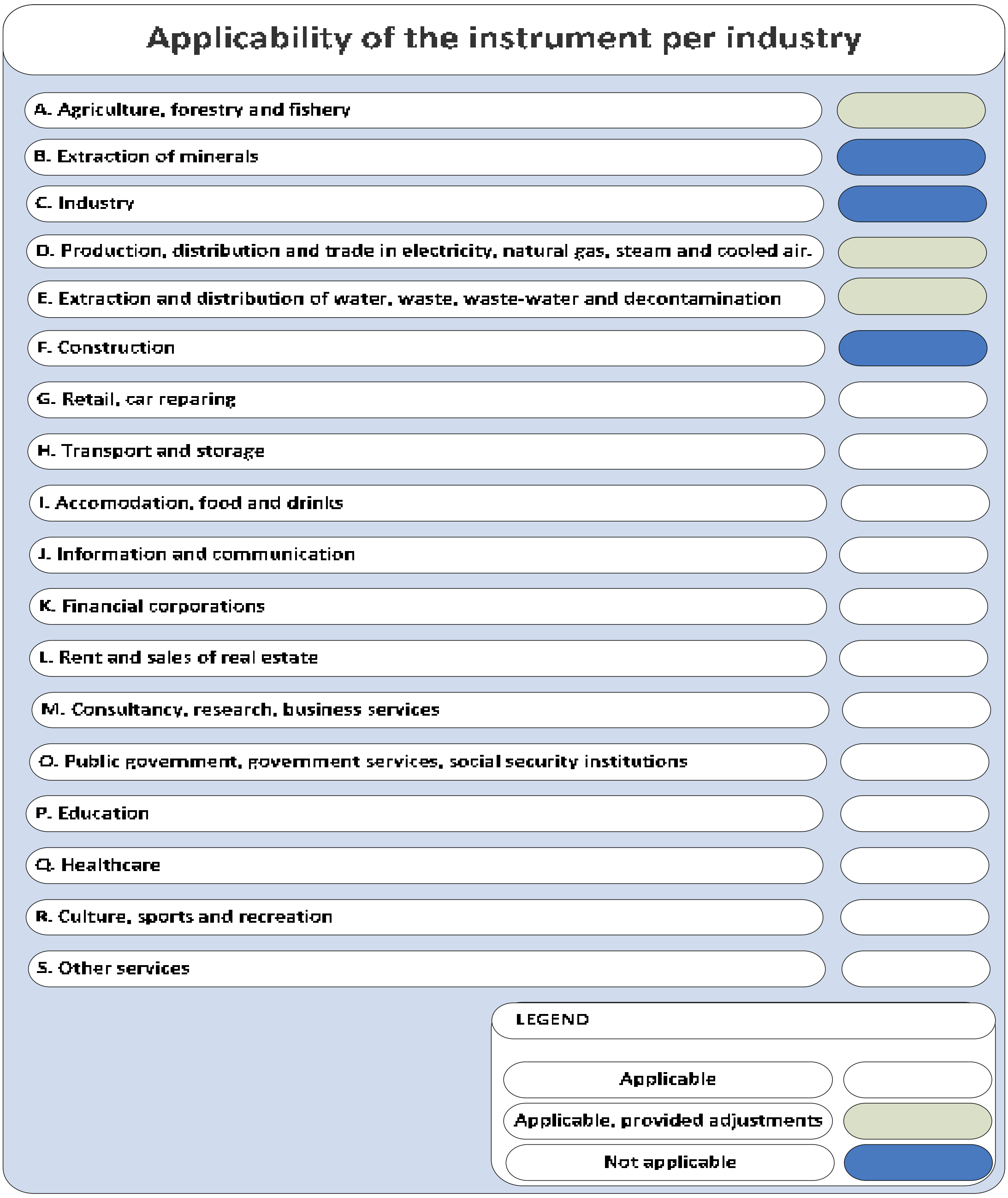


Figure 16 Results expert interview: general applicability of the instrument

The expert judgment states that the instrument is applicable to 13 out of 18 sectors. The combined carbon and water footprint of the organization in these sectors can be determined by the instrument. These organizations are office-based. Most relevant sources of carbon emissions and water usage in these organizations are electricity usage, heating and cooling of buildings, transportation and direct water extraction from the municipal supply. These categories are well represented in the instrument. Changes are required If the instrument is applied to the categories A, D and E (agriculture, forestry, fishery and production, distribution, trade of electricity and the extraction and distribution of water). To make good estimates for agricultural organizations the emissions from usage of fertilizers, storage of manure and the natural intestines process of livestock must also be included. For the production and distribution of electricity, the instrument currently provides the ability to make general estimates, however, if the instrument is applied to specific organizations within this sector, additional information is necessary on the different methods of producing and transporting. For the water sector the emissions due to the open air storage and waste water treatment facilities must be added into the instrument. Application of the instrument to organizations that are operating in the industry, extraction of minerals or the construction sector is not possible. The large differences in processes in these industries require expert knowledge and specific analysis. Analysis of the carbon emissions and water usage of these type or organization can be supported by the instrument, but requires additional information and calculations.

The instrument is expected to be applicable in 13 out of 18 sectors. No potential clients of Ernst & Young are present in the sectors in which it is not applicable. Most relevant industries are covered by the application domain of the instrument. General applicability can not be claimed, but the instrument does satisfy the wish from the client. To confirm the judgment from the expert more case studies can be performed. Preferred method is to apply the instrument to organizations from all different sectors.

6.1.2 A.2: Adoption of the conceptual model

When all elements of the conceptual model are included in the instrument it has adopted the conceptual model. This is a relevant check since the credibility of the instrument depends on the correct implementation of the theoretical foundations of the carbon and water footprint. If the conceptual model, based on existing theories from literature, is adopted correctly by the instrument this supports the credibility of the instrument and its outcomes. Testing this requirement is done by checking the adoption of the different sources and the scope that is taken into account by the instrument. The results are stated in Figure 17.

	I.1. CO_2 & H_2O Generation of purchased electricity, heat or steam	I.2. CO_2 & H_2O Extraction and production of purchased materials, fuels and products	Or.1. CO_2 & H_2O Generation of electricity, heat or steam	Or.2. CO_2 & H_2O Transportation of materials, products, waste and employees	Or.3. CO_2 & H_2O Physical or chemical processing and production	Or.4. Fugitive CO_2 emissions	Or.5. CO_2 & H_2O Extraction of water from municipal supply	Su.1. CO_2 & H_2O Leased assets, franchises, and outsourced activities	Su.2. CO_2 & H_2O Transportation of materials, products, waste and employees	Ou.1. CO_2 & H_2O Use of sold products and services	Ou.2. CO_2 Waste Disposal	Elements adopted into the instrument
Carbon emissions sources defined in theory												
Generation of electricity, heat or steam			v									v
Physical or chemical processes					v							v
Transportation of materials, products, waste and employees				v								v
Fugitive emissions						v						v
Generation of purchased electricity, heat or steam	v											v
Extraction and production of purchased materials and fuels		v										v
Transportation of materials, products, waste and employees in leased vehicles									v			v
Electricity related emissions	v		v									v
Leased assets, franchises and outsourced activities								v				v
Use of sold products and services										v		v
Waste disposal											v	v
Freshwater usage sources defined in theory												
Generation of electricity, heat or steam			v									v
Physical or chemical processes					v							v
Generation of purchased electricity, heat or steam	v											v
Extraction and production of purchased materials and fuels		v										v
Leased assets, franchises and outsourced activities								v				v
Use of sold products and services										v		v
Consumptive water usage											v	v

Figure 17 Check of adoption sources defined in conceptual model in the designed instrument

Figure 17 shows the results of the cross-check of the adoption of the essential elements of the carbon and water footprint concepts into the instrument. All elements are taken into account in the instrument. Based on this test it can be stated that requirement A.2 is fulfilled.

6.1.3 A.3: Validity of outcomes

If the output of the instrument is similar to the actual combined carbon and water footprint of the organization the outcomes are valid. The difference between the outcomes of the instrument and existing datasets determines the validity of the outcomes. No dataset is available that represents the results of the combined carbon and water footprint of an organization. Therefore another approach to test the validity of the outcomes is adopted. An expert has reviewed the individual calculations, used datasets and assumptions to estimate the error in the outcomes. Figure 18 shows the outcomes of the review. The full report of the interview is included in Appendix D.

Category	Range of error
Inbound	
I.1 Purchased electricity, heat or steam	< 5% - 10%
I.2 Purchased products, goods, materals	< 50%
Organizations	
O.1 Production of electricity, heat or steam	< 5% - 10%
O.2 Transport of materials, products, waste and employees	<20%
O.3 Physcial or chemical processing	n.a.
O.4 Fugitive emisisons	n.a.
O.5 Consumptive water usage	< 5% - 10%
Outbound	
Ou.1 Use of sold products and services	n.a.
Ou.2 Waste disposal	< 20%
Support	
Le.1 Leased assets, outsourced activities	n.a.
Le.2 Transport of materials, products, waste and employees	<20%

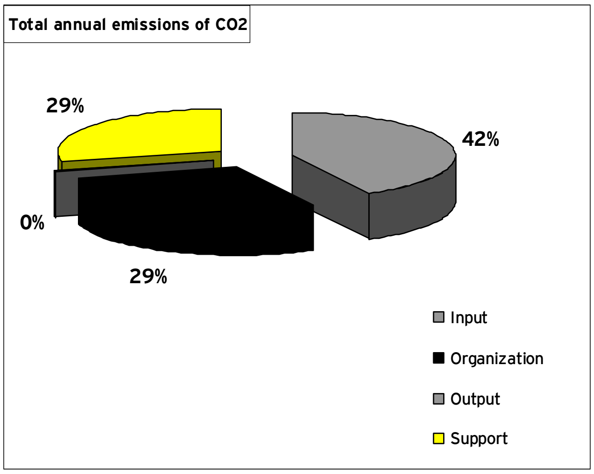
Figure 18 Estimated errors of calculations

The largest error is expected in the tab of Purchased products, goods and materials. Large simplifications cause the expectation of this large error. The lowest error is expected in the calculation of the environmental impact of the purchased electricity heat and steam. These calculations are well defined and the adopted conversion factors are expected to be accurate.

Boundary condition for the client was the total error of the calculation to be within +/- 30%. Based on the expert judgment it can be stated that this was fulfilled for all but one calculation. The calculation for the purchased products, goods and materials is expected to exceed this limit. This error must be taken into account during interpretation of the results. The error of the total calculation is still expected to be within the stated boundary. Therefore it is acceptable for the client, but requires extra attention. To confirm the judgment of the expert it is advised to perform additional research. The additional conversion factors expected to be published by the CBS offer opportunities for improvement.

6.1.4 A.4 & A.5 Identification main drivers of the footprint

The instrument must be able to identify the main divers causing the size of the footprint. If the application of the instrument results into the identification of the main drivers of the footprint it is stated to be fulfilled.



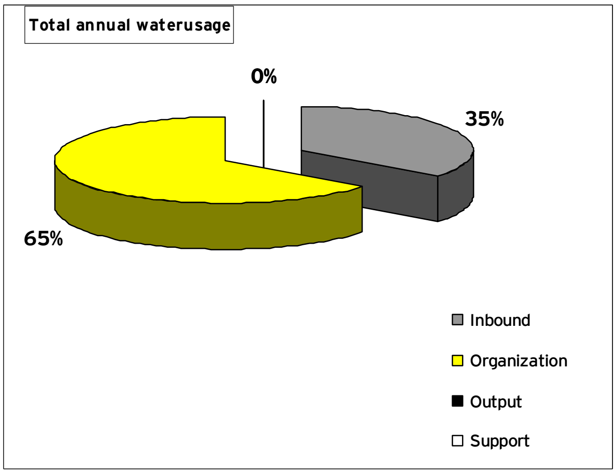


Figure 19 Results case study TU Delft

Figure 19 presents part of the results of the case study performed at the TU Delft. It represents the different parts of the organizations and the total annual emissions of CO_2. Main drivers are present in the 'Input' (42%), 'Organization' (29%) and the 'Support' (29%). The water usage is caused for 65% by the 'Organization' and 35% by 'Inbound'. This indicates the relevance of the purchase policy for the water usage of the organization.

Source	Emission CO2/year	
Generated electricity	2.124.641,96	11,16%
Generated heat	16.885.908,26	88,67%
Transportation of materials, products, waste and employees	0,00	0,00%
Physical, chemical production processes	0,00	0,00%
Fugitive emissions	0,00	0,00%
Consumptive Water extraction	32.136,82	0,17%
Total:	19.042.687,04	100,00%

Figure 20 Annual emissions TU Delft, category 'Organization'

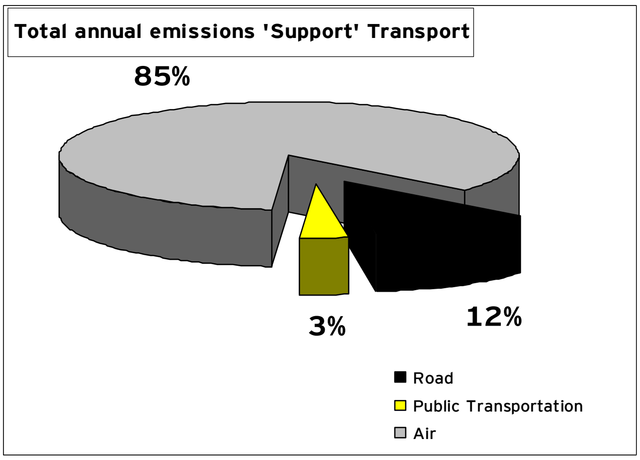


Figure 21 Annual emissions TU Delft, transport

The main driver of the annual carbon emissions from the transport category of the TU Delft is the use of air transport.

The results from applying the instrument show that it is able to identify the main drivers of the combined carbon and water footprint of the organization. From this it is concluded that the requirements A.4 and A.5 are fulfilled by the instrument.

6.1.5

A.6: Ability to calculate the full footprint

The instrument must be able to calculate the full footprint as defined in the conceptual model. If all elements from the conceptual model are quantified it is stated that the instrument is able to fulfill this requirement.

In its current form the instrument is unable to calculate the full footprint as defined in the conceptual model. Defining the calculations for the elements 'Physical or chemical processes' , 'Leakages' , 'Use of sold products and services' , and 'Leased assets' could not be completed. Calculating the emissions and water usage of the activities in these elements is not possible under the given constraints. A tailor made approach is necessary for this. Another element is the availability of the conversion factors for water usage. Due to the low maturity level of this concept these factors are not available for all activities. One of the main reasons for the difficulties to determine the water element is the availability of information on the virtual water content of products, but also the form in which the information is available within the organization. Example is the calculation of the carbon and water footprint due to transportation. The information on the impact of fuels on the usage of water is available on the level of the combustion of a certain amount of a specific type of fuel. However, it was found necessary to also support the calculation of the transport emissions based on mileages or other averages. This is done because this information is sometimes only available in this form. For these categories, the information of water consumption is not yet available.

From what is stated above it is concluded that the instrument is not able to calculate the full footprint as defined in the conceptual model. The client has accepted the limited application domain of the instrument in its current form. The elements which are not specified in the instrument are not critical for determining the footprint of the organizations within this domain. For scientific interest this part requires extra research to be solved. Additional attempts from experts within the difficult sectors to determine calculation is a possibility to overcome the specification problem. To overcome the lack of available conversion factors on water additional research must be performed to identify these factors.

6.1.6 A.7: Comparable with peers

If the results of the instrument allow comparison between different organizations it is stated that the results are comparable. The comparability of results is not only depending on the outcomes of the instrument. The input that is used to perform the calculations plays an important role as well. Validity and reliability of the information is an important element. Having assured this condition is fulfilled during the two case studies allows testing this requirement.

Comparable results		
Name of organization:	Delft University of Technology	
Time period of study:	01-01-2008 / 31-12-2008	
Characteristics of organization		
Total number of employees (fte's)	4.433,00	fte
Total annual profit	69.400.000,00(*)	Euro
Total annual carbon emissions / employee	12,96	tonCO2/employee/year
Total annual water consumption / employee	77,33	m3Water/employee/year
Total annual carbon emissions / profit	0,83	kgCO2/euro/year
Total annual water consumption / profit	4,94	lWater/euro/year
(*) number influenced by incidental insurance payment		

Figure 22 Comparable outcomes instrument

Figure 22 shows the output of the instrument. It includes indicators that are fit for comparison. The amount of carbon emissions and water usage per organization is indexed to the amount of employees (fte) and the annual profit (€). This allows comparison of the outcomes. Before these results are compared to any other organization, it must be determined whether the organizations have provided the information within the same scopes. If the conceptual model is fully adopted and all information within the elements is gathered, then the results are fit for comparison without doubts. Otherwise the different element of the organization can be compared, for example by taking the result of the 'organization' tab only.

Due to the limited number of case studies the testing of this requirement was limited. For the case studies as performed it can be stated that the requirement was fulfilled and the output allows comparison between peers. Additional case studies increase the insight in this element further and are recommended.

6.2 Non-functional requirements: Constraints

6.2.1 B.1: Duration of applying the instrument

The duration of applying the instrument must not exceed 30 working-hours. This includes both the time from the advisor as well as from the client. This requirement was tested by measuring the total time necessary to apply the instrument to the two case studies.

Duration of application of the instrument					
	Activity:	Duration (hours)			
		Case 1: TU Delft		Case 2: EY NL	
		Adv.	Client:	Adv.	Client:
1.	Define organization	1	0	1	0
2.	Determine required input	2	1	2	1
3.	Identify relevant sources	3	1	3	1
4.	Gather data	3	4	4	6
5.	Process data	4	0	4	0
6.	Report results	1	1	1	1
		14	7	15	9
	Total duration:		**21**		**24**

Figure 23 Duration of application of the instrument

The case studies were performed within 4 weeks, measured from the first contact until the reporting of the results. During this time the work that was performed by the user of the instrument was logged and measured. The total amount of time spent on these cases did not exceed the maximum amount of time that was available for the case study, as stated in Figure 23. The identification of the boundaries of the research is the first activity that is performed before the determination of the required inputs and the identification of the sources of information within the organization. The data gathering process requires the establishment of contacts with the different information sources. Gathering of the data is done by the employees of the organization, who have access to the systems and the knowledge to acquire the correct data. After the data gathering was finished, the processing of the results was performed quickly by using the interface of the instrument.

The requirement of the maximum duration of the application of the instrument has been fulfilled during the case studies. Due to time constraints, the search for information has been stopped after a fixed period of time, the result is that the case study finished on time, but not all information was collected. It is expected that within the remaining time the data could have been collected, however this was not tested. Performing additional case studies without time constraints can provide insight into this further.

6.2.2 B.2: Availability of information

The instrument must make use of available information from the organization. This was tested during the two case studies. Figure 24 shows the availability of data which was required for performing these cases.

Making use of the organization specific information that is readily available in the systems proved to severely decrease the amount of effort needed to gather all data. The experiences during the performed case studies learned that this element was a crucial factor in the speed of the data gathering process. By demanding information that was readily available the different contact persons were willing to co-operate easily. When information was asked that was not readily available, the attitude changed quickly to ‘that is impossible, we don’t have those numbers available’. Therefore it was very important for the information request to concern readily available information as much as possible.

It was found that the data on the consumption of electricity, gas and municipal water was easily available and well documented. The total use of transport, owned or leased, was also well available. In the case of lease-contracts the lease-organization has information that is well documented and easily accessible. Also the use of electronic fuel purchasing systems such as the company card that can be used to pay for fuel makes the data of transport available into large detail. The financial administration was also found an important source of information. The administration of the waste disposal was also well organized by the organization itself, but also by the waste-processing corporation. More difficulty was experience with the data for the element Extraction and production of purchased materials, fuels and products.

The test indicates that not all the required information was readily available within the organization. Although the largest part was available this is a concern. The more difficult indirect part of the footprint needs to be determined as well. The financial administration is expected to provide relevant data. It is recommended that during additional cases this element is evaluated further.

Availability of information case studies	
	Case TU Delft: **Results:**
I.1 Generation of purchased electricity, heat or steam	
Purchased electricity	Acquired all data 67.376.412,00 kWh
Purchased heat	Not relevant
I.2 Extraction and production of purchased materials, goods and products	
Amount spent per category of industry	Acquired part of data € 3.142.411,25 • expenses on electrical equipment € 8.556.779,61 • expenses on furniture € 10.102.314,22 • expenses on office equipment
Or. 1 Production of electricity heat or steam	
Electricity production	Acquired all data 1.084.001,00 m^3
Heat production	Acquired all data 8.615.259,32 m^3
Or. 2 Transport of materials, employees, products and waste	Not relevant for this case
Or. 3 Physical or chemical processing and production	Not relevant for this case
Or. 4 Leakages of carbon and water	Not relevant for this case
Or. 5 Extraction of water from municipal supply	
Extraction of water	Acquired all data 221.511,00 m^3
Ou. 1 Use of sold products and services	Not relevant for this case
Ou. 2 Waste disposal	
Tons of waste	Paper and cardboard 324,56 ton Residual waste 32,19 ton Glass 8,61 ton Metal 135,66 ton
Su. 1 Leased assets, franchises and outsourced activities	Not relevant for this case
Su. 2 Transportation of materials, employees, products and waste	
Travelled miles in leased vehicles / fuel consumption	Spent on road kilometers € 494.791,00 Spent on air kilometers € 8.994.857,00 Spent on public transportation € 1.700.969,00

Figure 24 Availability of data

6.2.3 B.3: General information from trusted sources

The calculations made in the instrument contain both a general and organization specific part. Therefore it is essential to identify the credibility of the sources of the general part. The validity of the instrument depends on the accuracy of this information. Adopting information from trusted sources contributes to the credibility of the instrument.

List of sources used	
I.1 Purchased electricity, steam or heat	
Emission factors production electricity:	Stroom etiketten 2008, NL
Water consumption production electricity:	National Renewable Energy Laboratory, USA
I.2 Purchased Products, goods, materials	
Emission factors spent Money per category	Central Bureau of Statistics, NL
Water consumption spent Money per category	Central Bureau of Statistics, NL
O.1 Production of electricity, steam or heat	
Emission factor production electricity	CE Delft, NL
Water consumption production electricity	National Renewable Energy Laboratory, USA
Emission factor combustion natural gas	SenterNovem, NL
O.2 Transportation of materials, products, waste and employees	
Emission factor spent Money per modality	Central Bureau of Statistics, NL
Emission factor combustion fuels	GHG Protocol, E.P.A. UK
Emission factor per mileage	GHG Protocol, E.P.A. UK
Water usage consumption of fuel	Hoekstra, Chapagain, Water footprint Network
O.2e Transportation of materials, products, waste and employees	
Emission factor mileage per modality	Central Bureau of Statistics, NL
O.5 Consumptive water usage	
Emission factor production of drink water	CE Delft, NL
Ou.2 Waste Disposal	
Emission factor disposal of waste	CE Delft, NL

Figure 25 List of sourced used for calculation in the instrument

Figure 25 shows the list of sources used. The Dutch institutions, CBS, CE Delft, SenterNovem and the WFN are well known institutions and leading authorities in their fields of expertise. The E.P.A. UK agency is connected to the GHG Protocol Initiative and provides basic data on the emission due to combustion in mobile equipment. The National Renewable Energy Laboratory is part of the ministry of Energy of the United States; this institute performs leading research in renewable energy and is well known as well. Based on the used sources it can be stated that requirement B.3. is fulfilled.

It is recommended to check this information for updates. The emission factors change due to technical development and new insights. To keep the instrument up-to-date it is important to contact these sources to ensure this.

6.2.4 B.4: Use available hard- and software

The instrument was developed in the spreadsheet program Excel 2003 Professional Edition, this is the most used spreadsheet program and therefore compatible with almost every computer system in the world. This requirement was fulfilled without a doubt.

6.2.5 B.5: Self explanatory

The instrument must be self-explanatory to the user. The future user is an advisor from Ernst & Young, as explained in paragraph 4.2. To test this requirement a usability test was performed with a representative from the client.

The participant was able to fill in the data into the instrument within 30 minutes. Some difficulties were present in determining the correct way to enter the data into the instrument. Main difficulty was in finding the correct match between the level of detail in the information provided by the organization and the appropriate tab. This confusion resulted into some errors in filling in the data. The structure of the instrument and the consistent adoption of the conceptual model provided clarity for the user. For the different flaws made, improvements were suggested and implemented. The users' judgment on fulfilling this requirement was 8 out of 10 and is an indication for the fulfillment.

It is concluded from these findings that the instrument fulfills the requirement B.5 of being self-explanatory to the user. In the discussion with the participant it became clear that many of the issues were solved by implementing the suggested improvements but also some problems remained. These problems are concerned with the understanding of the user of the instrument regarding the meaning of the different elements, the interpretation of them and the lack of experience in this field. Solution to this is to provide some basic education for the future user in determining a footprint.

6.2.6 B.6: Well documented

The instrument must be well documented with information supporting the application and maintenance. This requirement is fulfilled due to the extensive reporting on the research in this Master thesis report. Furthermore the instrument was supported with a quick-guide including the basic information on the instrument.

6.2.7 B.7: Easily maintainable

The instrument must be easily maintainable to keep the information up-to-date. This requirement could not be tested since the instrument is not in use yet. It is expected that the requirement is fulfilled due to the documentation which is supporting the application and maintenance of the instrument. The future user must appoint an administrator that will maintain the instrument.

6.3 Non-functional requirements: Quality requirements

6.3.1 C.1: Support of analysis

The output of the instrument should support the analysis of the results. The results of the case studies are analyzed to check the fulfillment of this requirement. The output provides the basic information such as the total amounts of both carbon emissions and water usage. Besides this information it also shows the impact per category, and if required also per emission source. The analysis of the results is mainly focused on identifying the different sources and their absolute and relative impact; these questions are supported by the provided output of the instrument. The output of the instrument does support the analysis of the results. It is stated that this requirement was fulfilled by the instrument. It is recommended that the output of the instrument is adapted to future demands of clients. Tailor made output increases the insight into the footprint.

6.3.2 C.2: Fit for reporting

The output from the instrument is presented as tables and graphs. The figures as adopted in the appendices are directly taken from the output of the instrument. The appendices are reports containing the results from the case studies. It is stated that the output from the instrument is fit for reporting.

6.3.3 C.3: Interpretable for non-experts

The output of the instrument must be interpretable for non-experts. During the usability test it was found that interpreting and presenting the results requires some expertise in the field of carbon and water footprints. Therefore it is stated that the output is interpretable for non-experts if presented by someone with some expertise. It is recommended to educate the future user of the instrument with basic expertise on the combined carbon and water footprint.

6.3.4 C.4: Attractive lay-out

The lay-out of the output of the instrument must have an attractive lay-out. Judging this requirement is subjective. During the usability test with a representative from the future user it was found that this requirement was fulfilled. Adapting the lay-out of the output to the demands of the customer is recommended.

6.3.5 C.5: Accepted indicators

The instrument must provide output in accepted indicators. Figure 26 gives the output for the carbon emissions as an example. The standard in reporting on carbon emissions is set by the Greenhouse Gas Protocol. This defines three scopes of reporting. Per scope the sources of carbon emissions are defined. This requirement has been fulfilled by the instrument.

GHG reporting scopes		
	kg CO2	kg CO2
Total emissions Scope 1:	**19010550,22**	**2900800**
Production of electricity	2.124.641,96	0,00
Production of heat	16.885.908,26	2.900.800,00
Production of steam	0,00	0,00
Transportation of materials, employees, products	0,00	0,00
Physical / Chemical processes	0,00	0,00
Fugitive emissions	0,00	0,00
Total emisisons Scope 2:	**25.872.544,13**	**3.864.200,00**
Purchased electricity	25.872.544,13	3.864.200,00
Purchased heat	0,00	0,00
Purchased steam	0,00	0,00
Total emissions Scope 3:	**10.262.978,27**	**18.633.708,75**
Use of sold products and services	0,00	0,00
Waste disposal	217.077,48	533.847,50
Outsourced activities	0,00	0,00
Transportation of materials, employees, products	10.045.900,79	18.099.861,25

Figure 26 Example of accepted indicators

6.4 Conclusion: evaluation of the instrument

This paragraph states the conclusions from the evaluation; this is done per category of requirements. All requirements are stated in the summarizing figures, the requirements which were not completely fulfilled are discussed.

Figure 27 presents the results from the evaluation as described in paragraph 6.1. Testing the general applicability (A.1) resulted in stating the application domain in which the instrument is applicable in Figure 16. The instrument is not generally applicable since it can not be applied in the industrial sectors and only in the agricultural and energy sector if additional calculations are specified. Testing and further improving is advised by applying of the instrument to organizations from these sectors. The evaluation of the validity of the results produced by the instrument (A.3) resulted in expert estimations of errors. Two important conclusions are stated. First the evaluation method can be improved by performing quantitative analyses and this is strongly recommended to obtain more accurate results. Second the estimated errors are within the range as defined by the client. This requires attention during the interpretation of the produced results of the instrument. But this does not jeopardize the identification of the main drivers of the organizations' footprint.

Evaluation of functional requirements	
A.1 The instrument must be generally applicable to any type of organization	
Tested:	Due to time constraints tested with an expert interview
Results:	Applicable to 13 out of 18 sectors
Conclusion:	Most relevant industris for client are coveren, acceptable for the client
Recommendation:	Additional research is advised, apply the instrument to more cases
A.2 The instrument must adopt the conceptual model	
Tested:	Tested by desk test
Results:	The instrument adopts the conceptual model
Conclusion:	Requirement is fulfilled
A.3 The instrument must produce valid results	
Tested:	Due to time constraints tested with an expert interview
Results:	The errors range from <5% up to <50%
Conclusion:	Total error lies between -30% and 30%, therefore acceptable for the client
Recommendation:	Additional testing by comparison; improve conversion factors adequateness
A.4 The instrument must be able to identify the most relevant factors causing the size of the footprint	
Tested:	Two case studies were performed
Results:	The most relevant factors are identified
Conclusion:	Requirement is fulfilled
A.5 The instrument must be able to determine the absolute and relative impact of the factors	
Tested:	Two case studies were performed
Results:	The absolute and relative impact were determined
Conclusion:	Requirement is fulfilled
A.6 The instrument must calculate the full footprint as defined in the conceptual model	
Tested:	Two case studies were performed
Results:	Not all elements are specified with calculations, not all conversion factors available
Conclusion:	Essential elements are specified, this is acceptable for the client
Recommendation:	Additional research is required to specify other elements and conversion factors
A.7 The instrument must produce output in a format that enables comparison of results with peers	
Tested:	Two case studies were performed
Results:	The results from the instrument allowed comparison
Conclusion:	Requirement is fulfilled
Recommendation:	Indicators can be improved with insight from additional case studies

Figure 27 Evaluation of functional requirements

The ability of the instrument to calculate the full footprint as defined in the conceptual model (A.6) is limited. Not all elements could be quantified into general calculations. Time limitations, lack of information and the characteristics of the processes these elements represent do not allow fulfilling this requirement. Tailor made solutions to specific cases is recommended to overcome this shortcoming. However for the application domain in which the client operates the instrument has sufficient functionality, although this will always require partly tailor made solutions. The other requirements have been tested properly and have been fulfilled by the instrument.

Evaluation of non-functional requirements (1)	
B.1 Applying the instrument should not exceed 30 man-hours	
Tested:	Two case studies were performed, with limited time
Results:	Applying the instrument in both cases did not exceed 30 hours
Conclusion:	Requirement is fulfilled but needs extra testing
Recommendation:	Performing additional case studies, acquiring 100% of the data
B.2 The instrument should make use of organization specific information readily available	
Tested:	Two case studies were performed, with limited time
Results:	Not all required data was readily available
Conclusion:	Acquiring all data requires additional work during the application
Recommendation:	Needs further evaluation during additional case studies
B.3 The instrument should make use of general applicable information from trusted sources	
Tested:	Checklist of used sources
Results:	The general data origins from trusted sources
Conclusion:	Requirement is fulfilled
Recommendation:	Contact sources for updates
B.4 The instrument should make use of available hard- and software at Ernst & Young	
Tested:	Availability is checked with IT department
Results:	The instrument uses Excell which is available
Conclusion:	Requirement is fulfilled
B.5 The instrument should be self-explanatory to the user	
Tested:	Usability test is performed
Results:	The instrument was self-explanatory to the user
Conclusion:	Requirement is fulfilled
B.6 The instrument should be well-documented to support the application	
Tested:	Usability test is performed
Results:	The documentation was sufficient to support the application
Conclusion:	Requirement is fulfilled
B.7 The instrument should be easily maintainable to keep information up-to-date	
Tested:	Tested by desk test
Results:	It is expected that the documentation support this
Conclusion:	Requirement is fulfilled
Recommendation:	Appoint administrator, create ownership

Figure 28 Evaluation of non-functional requirements: constraints

Figure 28 represents the results from the evaluation as stated in paragraph 6.2. The time limitation of 30 man-hours (B.1) could not be tested during the case studies. Although the results acquired during the case studies suggest that these limits can be fulfilled when 100% of the required information is collected this is only an indication and this needs to be confirmed in additional tests. In addition to this the use of readily available information (B.2) could not be fulfilled completely. The required information during the case-studies was not always readily available in the information systems. More effort is required to obtain all necessary information from the organization that is subject of study. The future maintainability of the instrument (B.7) can only be predicted. It is expected that the documentation will lighten the burden of maintenance. It is recommended that an administrator is appointed who will take the responsibility for this.

Evaluation of non-functional requirements (2)	
C.1 The output could support the analysis of the results	
Tested:	Case studies provide output, this was evaluated in desk test
Results:	The output support analysis of the results
Conclusion:	Requirement is fulfilled
Recommendation:	Adapt output to future demands
C.2 The output must be fit for reporting	
Tested:	Case studies provide output, this was evaluated in desk test
Results:	The output is fit for reporting
Conclusion:	Requirement is fulfilled
C.3 The output must be interpretable for non-experts	
Tested:	Usability test
Results:	Interpreting the output requires some expertise
Conclusion:	Requirement is not fulfilled
Recommendation:	Educate future users with basic expertise
C.4 The output of the instrument must have an attractive lay-out	
Tested:	Subjective judgment during usability test
Results:	The lay-out of the output was found attractive
Conclusion:	Requirement is fulfilled
Recommendation:	Adapt lay-out to future demand
C.5 The output of the instrument must include accepted indicators	
Tested:	Case studies provide output, this was evaluated in desk test
Results:	The output support analysis of the results
Conclusion:	Requirement is fulfilled
Recommendation:	Adapt output to future demands

Figure 29 Evaluation of non-functional requirements: Quality

Figure 29 contains the results of the evaluation as described in paragraph 6.3. The results of the instrument need to be interpretable for non-experts (C.3). The usability test indicated that this causes problems. The interpretation of the results requires some basic knowledge of carbon and water footprints; this results in the necessity to educate the future users on this topic. The documentation is expected to support this. Additional information sessions are required to at least educate the future administrator of the instrument. The other 'C' requirements have been fulfilled but it is recommended to adapt these elements of the instrument during further experiences.

The requirements of the instrument have been fulfilled to an acceptable level for the client, Ernst & Young. General applicability, validity of outcomes and specification of all calculations requires extra attention before the instrument is applied. The availability of information within the organizations and the total time of acquiring this could only be predicted based on the evaluation. These important constraints require further insight which could be acquired during further application. The interpretability of the outcomes by non-experts requires extra education and the appointing of a administrator. The evaluation results in the verdict of this instrument being a good tool that is ready for application to provide quick insight into the combined carbon and water footprint of organizations. However for more detailed insight and more accurate results extra research is required from the development perspective. Also future publications need to be monitored which could provide more accurate conversion factors for further improvements.

6.5 Guidelines for future application of the instrument

Based on the results of this chapter five guidelines are stated which must be adhered to when applying the instrument in its current form. Successful application is achieved if insight is created in the carbon and water footprint of an organization. This requires the calculations to be performed correctly and represented in the output. Before this step the data gathering must be performed successfully, the right data must be collected within the limited time. Besides these conditions the results of the evaluation require additional guidelines for applying the instrument.

1. Match with type of organization

Only if the organization has characteristics which are similar to those organizations which are defined in Figure 16, the instrument can be applied. Application in different industries will require additional analysis. Also the level of detail that is required to determine the combined carbon and water footprint of organization with complex processes will be far too high and result in infringement of time budgets. Without the condition of a good match between the instrument and the organization successful application is not possible.

2. Sense of urgency at the client

Co-operation from the clients-side is required to obtain the necessary data. Due to the fact that the information is stored in electronic databases and requires authorization to access it is necessary to obtain the co-operation of the people that have this access. Without the sense of urgency at the client and the co-operation of employees with access to the information, successful application is not possible.

3. Required data must be available and accessible

The information which is necessary to perform the calculation must be available in information systems within the organization. This requires active or passive monitoring and storage of data. The financial administration is able to cover large parts of the necessary information when combined with billing documentation. Without the required data being available and accessible, the instrument can not be applied successfully.

4. Instrument must be maintained

To be able to maintain and apply the instrument it is necessary to appoint an administrator or owner of the instrument within the organization. This person becomes responsible for updating the conversion factors and supervision of the maintenance. After the instrument is applied to more case studies the experience gained during these cases can be used to further improve and expand the instrument. To produce valid results it is important that the used conversion factors for making the calculations are accurate. This requires active maintenance of the numbers used in the instrument. Updating should occur with a frequency of at least one year to be able to keep the data up to date. All used data can be found in the description of the instrument in Chapter 5. Furthermore it is important to monitor new publications on conversion factors. New developments in this field can result into more detailed calculations and insight into the organization footprint. With an outdated instrument successful application is not possible.

5. User must have basic knowledge of footprint

The user of the instrument that will be leading the analysis must have basic knowledge of determining a footprint. The conceptual model and the instrument provide guidance for the determination process but still require expertise from the user. Performing and leading the entire analysis does require basic knowledge of footprint. Without a user with some expertise in this field the instrument can not be successfully applied.

7 General approach to determine the combined carbon and water footprint of an organization

- *What approach can be stated for determining the combined carbon and water footprint of an organization? –*

Our developed conceptual model defines the combined carbon and water footprint of an organization (see paragraph 3.5). It states the sources of carbon emissions and freshwater usage within organizations. The instrument that was developed for our client, Ernst & Young, is a specification of this concept: an applicable instrument (see Chapter 5). Its limitations and conditions for application have been defined in paragraph 6.4 and 6.5. To enable the application of the conceptual model to other cases, we propose a six-step approach that enables the general application of the conceptual model. This approach is based on the used approach during the case studies which were performed for the evaluation of the instrument and is stated in Figure 30.

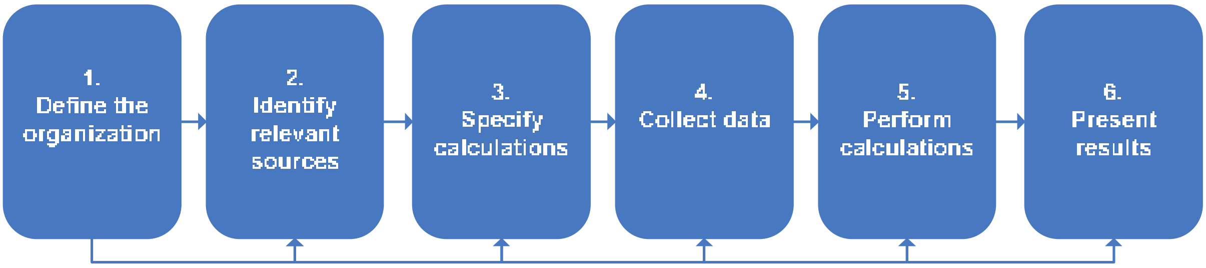


Figure 30 Six-step approach

The **first step**, defining the organization is done by setting the boundaries which clearly distinguish the organization from its environment. In this step the subject of study or the entity of the footprint calculation is clearly defined. With the organization clearly defined, the **second step** is to identify all relevant sources of carbon emissions and water usage that are present within the organization. The **third step** consists of the specification of all necessary calculations. For every relevant source of carbon emissions or water usage the necessary calculations must be determined. The **fourth step** is to collect the data that is necessary to perform the calculations. This means that for all the input variables of the calculations the necessary information needs to be collected. The sources of information within the organization need to be identified in close cooperation with the organization itself. Not all the required information will be readily available and might require extra effort to be collected. The **fifth step** is to perform the calculations. By inserting the collected data from the organization into the calculations the amount of carbon emissions and water usage of the organization can be determined. The **sixth step** consists of gathering all the results of the calculations and presenting them. This might seem obvious but this phase was specifically defined due to the importance of presenting the data in the right format. To be able to analyze the results of the calculation and to translate them into valuable information for the organization it is necessary to process the data into recognizable tables and figures.

Collecting the information requires the information to be available and accessible. The availability of the information is depending on whether it's monitored and registered into information systems. This can be done by the organization or a third party, for example the information on the mileage of the leased cars might be present at the lease company. The accessibility of the information is another aspect. The authorization to the required information must be available. In case of cooperating with third persons within the organization to collect the data it is necessary to create commitment. This can be done by persuasion or authority, depending on the type of organization. In case the information is not available or not accessible than the approach can not be applied.

The determination of the footprint is supported by the conceptual model. It supports the decisions that are necessary in the different steps of determining the carbon and water footprint as defined in the approach. The identification of the relevant sources is made possible due to the conceptual model. Regardless of the organization this can be used to structure the determination process. It clearly states what elements are to be taken into account, in what part of the organization they are present and whether they can be influenced directly or not, which is relevant for further actions. The identified sources of carbon emissions and water usage are defined and provide an exhaustive overview of all sources. Specifying the calculation of the values of the different elements completes this process. Based on input of organization specific data, the carbon emissions and water usage can be determined.

Communicating of the results is essential in the process of gaining insight into the carbon and water footprint of an organization. During the application of the instrument in several test situations, the adopted structure of the conceptual model turned out to be very effective in communicating the concept. Due to the recognizable categories the communication of the total concept could be done effectively. Interpretation of the output of the instrument also benefited from the adoption of the conceptual model. Due to the distinction made between the different parts of the footprint based on the basic structure of the organization, insight into the different drivers causing the size of the footprint is automatically made as well.

The proposed approach is expected to contribute to the application of the developed conceptual model. Since the instrument that was developed during this research has been tailored to the specific demands of the client, Ernst & Young, it is expected that in other situations different design choices are necessary. This means that the developed instrument in this research will not be sufficient and might require another specification of the conceptual model for different cases. Following the proposed approach enables other researchers and developers to benefit from the conceptual model to determine the combined carbon and water footprint of organizations.

8 Conclusions and recommendations

If we place ourselves again in the position of the CEO from the introduction of this report, the question is: have we acquired enough insight during this research into how to determine the environmental impact of the organization to support our decisions? The answer to this question is given in this chapter. First we answer the main research question by summarizing the answers to the sub questions which add up to answering the main question. Second we reflect on the research results from a scientific and practitioner's perspective. Third we recommend directions for future research.

8.1 Summary of results

As stated in the introduction of this report it is important to gain better insight into the environmental effects the activities of organizations cause. Due to the lack of valid methods which are able to produce valuable insight into the environmental impact of organizations the research objective was defined as: *to develop an instrument that is able to facilitate the determination of the combined carbon and water footprint of an organization*. Therefore the main research question was posed as:

How can the combined carbon and water footprint of an organization be determined?

To answer this research question, a design science research approach was adopted. This incurs the process of making use of the existing knowledge base to develop an innovative artifact, which after thorough evaluation contributes new concepts back to the knowledge base. The first step of this research was to identify the available concepts in literature that could form the foundation of the conceptual model of the combined carbon and water footprint; this involved the extraction of knowledge from the existing knowledge base.

The next step was to combine the concepts of the carbon and the water footprint into one conceptual model, integrating both concepts. After this the environment in which the artifact was to be used was analyzed. This resulted into a set of requirements from Ernst & Young which determined the design space for realizing the instrument, and stated the design challenge. Within the boundaries as set by the requirements and the theoretical concepts as determined the design phase of the instrument was started and concluded.

This resulted into a prototype of the carbon and water footprint instrument. Using rigor evaluation methods the extent to which the instrument was able to fulfill the requirements was determined. Based on the developed insight a general approach for determining the carbon and water footprint of organizations was proposed.

To answer the main research question first the answers to the separate sub questions are discussed separately, leading to the answer to the overall research question.

8.2 Answers to sub questions

Part I: Theoretical foundation: conceptual model for the combined carbon and water footprint

Chapter 2: What concepts for determining the carbon and water footprint can be derived from literature?

Four important aspects of determining a footprint have been distilled from literature: the entity, scope, sources and the calculation approach. The entity determines the object of study of which the footprint will be determined. The scope determines the boundaries that are chosen in which the environmental impact is determined. The sources determine what sources of environmental impact are taken into account. The calculation approach consists of the method that is used to determine the numerical values of the environmental impact. These elements determine the design space in which the choices are included, which are necessary to construct a footprint.

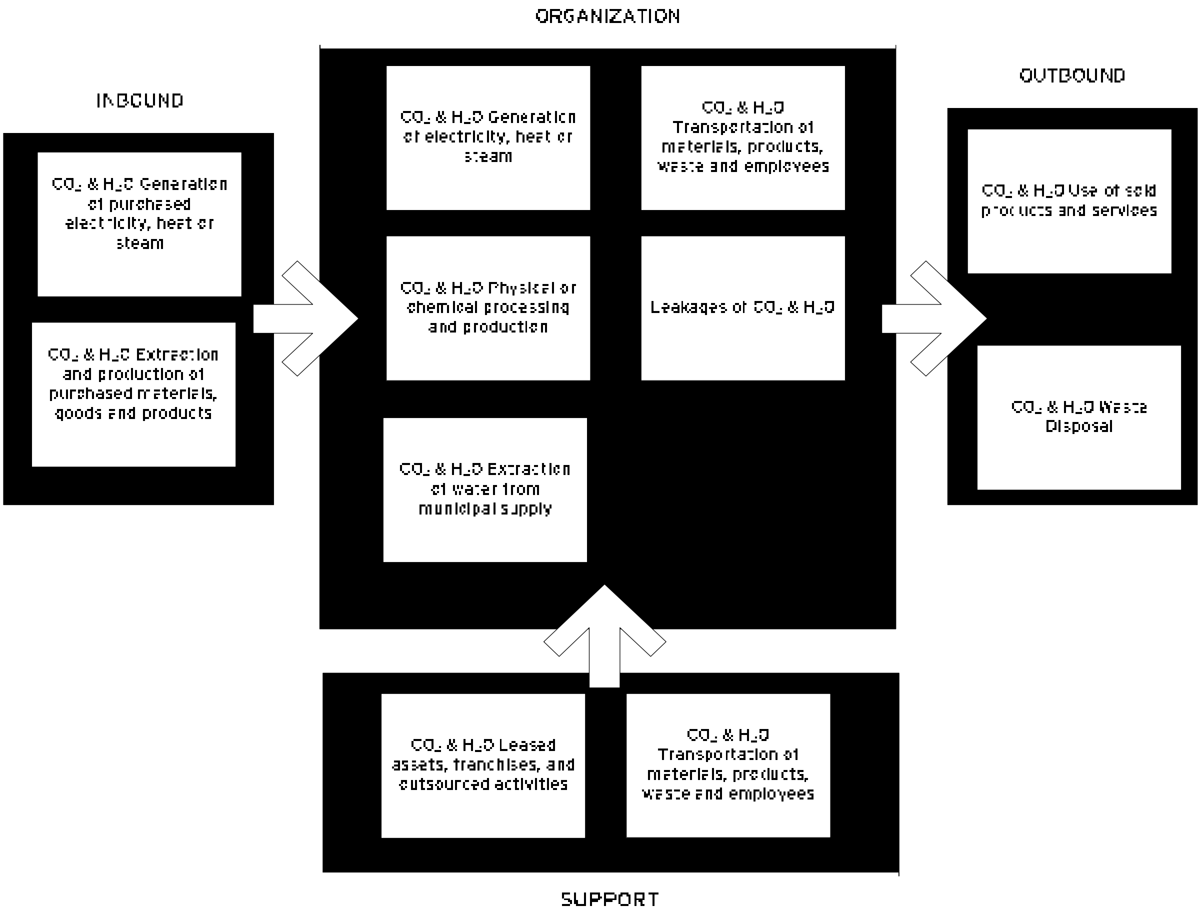
The concept of the carbon and water footprint of an organization is not available in literature. In the current available literature there is no developed or proposed concept for determining the combined carbon and water footprint of an organization. But, the separate concepts have been described. The carbon footprint of organizations has been clearly described in different publications and has resulted in the development of a standard approach: the Greenhouse Gas Protocol. This defines three scopes in which the carbon emissions of an organization can be taken into account. The first scope contains the emissions that are produced due to activities performed within the boundaries of the organization. The second scope is concerned with the emissions that occur during the production of the purchased electricity, heat or steam by an organization. The third scope consists of the emissions that have occurred or occur outside the boundaries of the organization, but do need to be accounted for. The emissions during the extraction and production of fuels are an example of this category. The direct emissions that occur from the combustion of the fuel need to be taken into account but in addition to this also the emissions that have already occurred are accounted for. The water footprint of organizations has been developed in concept by a single scientist. The proposed concept consists of taking into account both the direct and the indirect consumption of freshwater. A distinction is made between three types of freshwater, blue, green and grey. The concept of the Business Water Footprint has not been developed into maturity and has not been applied in practice. The geographical component of the water footprint must be taken into account to add meaning to the outcomes of the calculations. The impact of extracting water depends on the water scarcity that is present at the geographical location at which this takes place.

No concepts for the combined carbon and water footprint of an organization could be found in literature. The essential elements of the Greenhouse Gas Protocol and the Business Water Footprint determine the entity, scope and sources that provide the fundaments for developing the combined carbon and water footprint of an organization.

Chapter 3: What conceptual model for the combined carbon and water footprint of an organization can be designed based on the existing concepts?

The conceptual model for the combined carbon and water footprint of an organization is formed by the choices on the entity, scope, sources and calculation approach for the footprint as adopted from the existing concepts. The entity that is subject of the footprint study is 'an organization'. This is any entity that is undertaking economic activities. The scope of the footprint is to take into account both direct and indirect emissions and water usage of the organization. The direct emissions and water usage depends on the activities that are performed within the boundaries of the organization, with all assets that are owned by the organization. The indirect emissions and water usage are concerned with the activities taking place due to the activities of the organization, although not directly executed by the organization itself.

The sources of the indirect emissions have been divided among three parts of the organization, the inbound, outbound and support elements. The inbound is concerned with all energy and materials that are purchased into the boundaries of the organization. The support is concerned with the effect of the activities taking place in all leased or hired assets that take place due to the existing of the organization. The outbound element contains the environmental impact of the products and services that are leaving the organization and the effect of the disposal of waste.



Part II: Design challenge: an instrument for E&Y based on the conceptual model

Chapter 4: What are the requirements for the instrument that is able to calculate the combined carbon and water footprint of an organization?

The requirements for the instrument that is able to calculate the combined carbon and water footprint of an organization are determined by the setting in which the instrument will be applied. It is aimed at assisting the advisor-client relationship that is present during the process of gaining insight in to the combined carbon and water footprint of an organization. The requirements are determined in close interaction with the future user of the instrument and based on the expected wishes of the clients.

Functional requirements

The instrument must be able to determine the combined carbon and water footprint of an organization.

- A.1 The instrument must be generally applicable to any type of organization
- A.2 The instrument must adopt the conceptual model
- A.3 The instrument must produce valid results

The instrument must be able to identify the main drivers of the organizations' footprint.

- A.4 The instrument must be able to identify the most relevant factors causing the size of the footprint.
- A.5 The instrument must be able to determine the absolute and relative impact of these factors on the total size of the footprint.

The instrument must produce output that can be compared to other organizations.

- A.6 The instrument must calculate the full footprint as defined in the conceptual model
- A.7 The instrument must produce output in a format that enables comparison of results with peers

Non-functional requirements

Constraints

Applying the instrument is constrained by a limited budget.

- B.1 The duration of applying the instrument must not exceed 30 man-hours.
- B.2 The instrument must make use of organization specific information that is readily available in its information systems.
- B.3 The instrument must make use of general applicable information from trusted sources.
- B.4. The instrument must make use of available hard- and software at Ernst&Young

The instrument must be usable by a person with limited expertise of footprint studies.

- B.5 The instrument must be self-explanatory to the user
- B.6 The instrument must be well-documented to support the application
- B.7 The instrument must be easily maintainable to keep information up-to-date

Quality requirements

The instrument must produce well interpretable output

- C.1. The output must support the analysis of the results
- C.2. The output must be fit for reporting
- C.3. The output must be interpretable for non-experts

The instrument must produce outcomes that are fit for reporting

- C.4. The output of the instrument must have an attractive lay-out
- C.5. The output of the instrument must include accepted indicators

The requirements cause a trade-off between the completeness of the calculation on the one hand and the limitations due to time, knowledge and information availability. This set of requirements forms the basis for the design choices and for the evaluation of the performance of the instrument in a later stage.

Chapter 5: What instrument can be developed that is able to calculate the combined carbon and water footprint of an organization?

Based on the conceptual model as defined in chapter 2 and the requirements as were stated in chapter 3 an instrument was developed. The aim of this instrument is to facilitate the calculation of the carbon and water footprint of an organization with respect to the requirements. This resulted in a spreadsheet model that is able to perform the necessary calculations to determine the values of the identified elements of the combined carbon and water footprint.

The structure of the instrument is based on the basic structure of the conceptual model. The inbound element represents the environmental impact of all goods, products, services, utilities etc. that enter the boundaries of the organization, due to purchasing. The organization element represents the environmental impact due to all activities that occur within the boundaries of the organization. This boundary is determined by ownership, all assets owned by the organization are taken into account in this part. The outbound element represents the environmental impact of all the products and services and the waste that is leaving the boundaries of the organization. The support element represents the environmental impact of all assets that are used to support the activities of the organization, but are not directly owned by the organization. This includes leased cars, leased buildings and other assets.

Every element as defined in the conceptual model has a designated module in the instrument to calculate the carbon emissions and water usage. The calculations are based on combining organization specific information representing the activities of the organization with conversion factors representing the carbon emissions and water usage due to these activities. For some calculations different options were adopted. Based on the availability of the information within the organization, the appropriate option can be chosen.

Part III: Evaluation:

Chapter 6: To what extend is the prototype successful in determining the combined carbon and water footprint of an organization with respect to the requirements?

The evaluation of the instrument was performed by desk research, two case studies, an expert interview and a workshop to test the usability. The majority of the requirements is fulfilled by the instrument.

The general applicability of the instrument is constrained to certain industries. The evaluation of the instrument showed that the instrument cannot be applied to all industries in its current format. The chemical processes taking place in diverse production processes cannot be taken into account using this instrument. Furthermore the construction industry and the agricultural industry also contain to specific elements that are not taken into account by this general instrument. Although the requirement was not fully complied with, the majority of the industries in which Ernst & Young is active can be covered with the instrument.

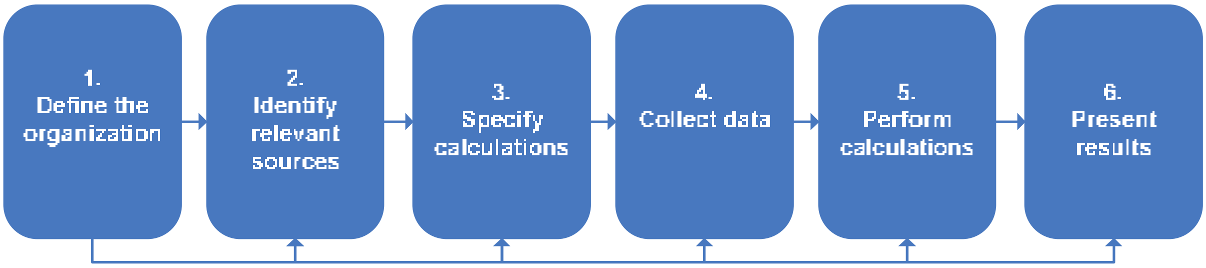
The validity of the results of the instrument differs per category. Due to the assumptions and simplifications, errors were introduced into the calculations. Although the errors are mainly depending on the accuracy of the information that is entered into the calculations, the calculation themselves also introduce small errors into the results. The impact due to the category of purchased materials, goods and products is determined by the size of the monetary transactions performed within a certain industry. Due to the large variety of products, the use of national data and the reduction into a small amount of categories the errors in this category are large. Interpreting the results from these calculations can only be done whilst taking into account this error.

The usability of the instrument was found to be in compliance with the stated requirements. Applying the instrument to two case studies, and having it tested by a future user indicated that the instrument was well applicable. The duration of applying the instrument was tested in the case studies and turned to be within the boundaries that were defined by Ernst & Young.

Five guidelines were developed which must be followed during application of the instrument. First guideline is to ensure the match between the type of organization and the application domain. Second there must be sense of urgency at the client's organization. Third, the required information must be available within the organization. Fourth, an administrator must be appointed for supervision on maintenance and usage of the instrument. And fifth, the future users of the instrument must have basic knowledge of footprints in order to apply the instrument.

Chapter 7: What approach can be stated for determining the combined carbon and water footprint of an organization? –

To determine the combined carbon and water footprint of an organization, six steps need to be performed. First, the entity or object of study needs to be identified by defining the organization. Second is the identification of the relevant sources of carbon emissions and freshwater usage. Third, to determine the impact of all relevant sources, the calculations need to be specified. Fourth is the collection of the necessary data. Fifth, by inserting the collected data into the calculations these can be performed. Sixth, the results of the footprint study need to be communicated effectively.



The developed instrument is able to support the application of the approach. This is possible in those cases in which there is a match between the type of organization and the application domain of the instrument, if there is a sense of urgency at the client, the required data is available and accessible, the instrument is kept up-to-date and the user of the instrument has basic knowledge of determining a footprint.

In case there is a mismatch between the type of organization and the application domain of the instrument, the conceptual model can be used to perform the determination of the footprint. This guides the decisions necessary on the scope, sources and calculations which are necessary to perform the footprint calculation.

8.3 Thesis conclusions

Based on the answers to the sub question and the experience gained during the realization of the research objective, the answer to the main research question can be stated.

How can the combined carbon and water footprint of an organization be determined?

The answer to this question is twofold:

First, the combined carbon and water footprint of an organization can be determined by applying the developed spreadsheet model, following the six-step approach with respect to the guidelines as defined in paragraph 6.5. In those cases in which these guidelines can be followed the application of the instrument is a good method for determining the combined carbon and water footprint of an organization.

Second, the combined carbon footprint of an organization can be determined by applying the conceptual model following the six-step approach. The developed spreadsheet model is the result of the specification of the calculation of the combined carbon and water footprint under the requirements that were defined by one client. In cases in which the requirements are different or when the conditions of applying the instrument can not be met this second approach is advised. The conceptual model provides the theoretical foundation for determining the footprint and is guided by the six-step approach. This approach enables the general application of the developed concept although is does require expertise in the field of footprints by those who apply it.

8.4 Recommendations for Ernst & Young

The developed instrument is useful in gaining insight into the combined carbon and water footprint of an organization. In its current state it can be applied to provide first insight to an organization without large research efforts. This provides the opportunity for Ernst & Young to perform quick-scans of clients as basis for further actions. The results can be used to identify the areas in which the potential lies to develop possible measures of reducing the footprint. However for detailed insight into the footprints additional research is required into specification of the calculations and adding conversion factors.

Appointing an administrator or 'super-user' is critical to the future use of the instrument. This person becomes responsible for updating the conversion factors and supervision of the maintenance. Updating should occur with a frequency of at least one year to be able to keep the data up to date since this is the frequency of publication of the relevant sources used. This person will require expertise in the field of footprint calculation to be able to supervise the application of the instrument.

Further specification of the calculations of the different elements of the spreadsheet model is expected to improve the validity of the instrument. Acquiring more detailed conversion factors enables the performance of more detailed calculations. This will on the one hand improve the level of detail in the results but on the other hand also increase the effort of data-collection during application. Between the level of detail and the effort of acquiring the data lays a trade-off which must be continuously evaluated during future efforts.

Thought leadership in the field of determining and reporting on the environmental performance of organizations can offer Ernst & Young a frontrunners position. Therefore we advise to continue with the development of methods and tools to support organizations in this growing business challenge. It is also expected that future developments in reporting on environmental performance and the future need for advices on achieving performance improvements results in new business opportunities.

8.5 Research limitations

The proposed approach supported by the instrument and the conceptual model provide structure and guidance to the difficult task of determining the combined carbon and water footprint of an organization. However some limitations of the research have been identified.

First limitation of the research is concerned with the performed case studies. These were executed under strict time constraints. This caused the ending of the data gathering phase before all data was acquired. This has influenced both the results and the evaluation of the instrument to large extent. This has several consequences. First, the results of the case study do not fully represent the combined carbon and water footprint of the organizations. Second, testing the ability of the instrument to stay within the time constraints could not be completed. This means the time necessary for future application to be an estimate. Another important aspect is the selection of the organizations at which the case studies were performed. Both Ernst & Young and TU Delft are organizations with characteristics of the service sectors. Therefore no experience was acquired in the other sectors. This choice was made based on the willingness to co-operate and the personal connections available. This causes uncertainties to the assumption that the conceptual model and the six-step approach are applicable in all industries and also a lack of insight into possible problems.

Second this research was performed for a specific client. This resulted into strict requirements for developing the instrument. This caused the focus of the effort on producing a practical applicable artifact and caused less focus on the level of detail in the calculations. Therefore the level of detail chosen for the calculations is adapted to these constraints. This has consequences for possible future applications under different requirements. If the goal of the research demands for high level of detail it might be necessary to replace them with more detailed calculations.

The third limitation is concerned with the adopted information on the water footprint. Since this concept has only been recently developed little information is available. The geographical component in the available information used for the calculations in the spreadsheet model is limited to the territory of the Netherlands. This has to be taken into account during the interpretation of the outcomes of the instrument since in its current form produces results that do not take into account this aspect.

Fourth, the conceptual model and the six-step approach have not been applied in practice to other cases and neither has this been done by third persons. The recommendations are therefore made to encourage future efforts in this field. This causes some uncertainties in the expected success of applying the model and approach to other cases, in different industries by third persons.

Finally during the evaluation phase no numerical validation could be performed due to the unavailability of data. Although other evaluation methods have been extensively applied this limits the certainty of the estimates for the expected errors of the instrument. Application of the instrument and interpretation of the results must take this limitation into account. Numerical validation can be applied in future work to overcome this lack.

8.6 Reflection research method

The design science research methodology has supported the search process which distinguishes this design science research from routine design efforts. It enabled the integration of the search for utility in designing the instrument and also the search for knowledge in the form of developing the theoretical conceptual model and the six-step approach. It is this support that has made the choice for this method valuable. The design process of the instrument also had the characteristics of a search process. Due to close interaction with the client and the numerous feedback loops the development of the innovative artifact became possible.

The thorough evaluation of the designed artifact resulted into additional knowledge which was used to develop the approach. It is this specific element of the design science approach that made this research different from other design efforts. By evaluating the application of the instrument it became possible to state the general approach for application of the conceptual model.

The requirements engineering methods of interviewing and prototyping supported the process of stating clear requirements. This approach helped us and the client to specify the requirements which were difficult to state upfront.

8.7 Further research

It is already stated in the conclusions of the evaluation chapter, paragraph 6.4 that additional effort is advised in the further evaluation of the instrument. Also the specification of the calculations and the search to additional and more detailed conversion factors is strongly recommended. Besides these recommendations already mentioned, four directions for further research are stated.

First, including the geographical component of the water footprint in reporting the results adds meaning to the outcomes. The already suggested approach of using the water scarcity index (see paragraph 3.6), is expected to provide a good basis for further developments. This would enable the possibility to report on the actual impact of the footprint of the organization, in addition to its size.

Second, additional ecological indicators can be added to the conceptual model. The chosen combination of carbon and water is based on the existing tradeoffs between these two indicators. Adding more ecological indicators to the calculation of the environmental impact of the organization is expected to lead to better insights. Possible elements are land use and extraction of non-renewable resources.

Third, additional research is advised to determine the trade-off between the different ecological indicators. The conceptual model as it has been developed does not facilitate the tradeoff between them. This requires specification of the expected impacts or other means of comparison. Possible outcome of this research effort can be a framework which supports decision makers within the organizations.

Fourth and final recommendation is the further application of the defined concept of the combined carbon and water footprint of organizations. We encourage researchers and practitioners to use the developed conceptual model, the approach and the developed spreadsheet model. We expect that additional experience leads to improvements and further developments of these concepts when applied in future research.

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EPA USA
Heineken
Nuon
Shell
Unilever
WWF

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Appendix

Appendix A: Expert interview

The goal of this interview was to obtain the opinion of an expert on the validity of the output of the instrument and the general applicability. Both issues are stated in requirements which form an important element of the evaluation of the instrument. The interview was held at the research and consulting organization CE located in Delft, the Netherlands. CE Delft is an independent research and consulting organization specialized in innovative solutions to environmental issues. The interview was held with Msc. H.J. Croezen, expert in the area of life-cycle analysis, environmental modeling, graduated in chemistry with expertise in the petrochemical industry. Due to his 13 year of experience in this field and contributions to publications, he was chosen as preferred expert for the interview. Previous to the interview the instrument was sent to the respondent including documentation to allow the respondent to prepare the expert interview. The main findings of the interview were documented into this report. The sentences starting with HC state the conclusions on the most important topics.

Structure of the instrument

HC: The structure of the instrument is very clear. By adopting the framework that is consistent to the general structure of an organization, the instrument is well interpretable and clear. The different sources of carbon emissions or water usage are good identifiable. Also the clear distinction between the activities performed within the boundaries of the organization and outside these boundaries is clear.

HC: The interface of the instrument is ok, but can be improved by providing some more guidance to the user of the instrument. Sometimes it is not clear what fields need to be filled out and which need to remain unchanged to allow the calculations to be performed correct. It is strongly recommended to improve this aspect of the instrument. It is expected that this can be done without large changes, but will have large positive results.

Comments on the different tabs

I.1 Purchased electricity, heat or steam

HC: This tab is clear; the usage of the conversion factors from the Stroometiketten provides a reliable and accurate basis for performing the calculations. The adopted conversion factor to determine the water usage due to the production of electricity heat or steam might cause some deviations from the actual value. Although the energy producing facilities in the United States (from which the figure is acquired) are similar to those in the Netherlands, the differences between the installations might introduce a small error. If the interest of the customer is oriented in acquiring insight into this specific element another indicator is suggested to improve the validity of the results. Another important remark was the suggestion how to take the environmental effects of purchased heat / steam into account.

I.2 Purchased materials, fuels, products and materials

HC: The application of this tab can cause confusion to the inexperienced user. Several comments can be made to this tab due to the large reduction of complexity that is applied to this particular element. The emissions and water usage due to the purchasing of materials, goods, products and services are a complex element. Several options for improvement were discussed, resulting into the advice to look at the program SIMAPRO to acquire more data regarding the ecological impact of purchased elements in these categories. (this advice has been taken into account, the program was analyzed but proved to be no option for improvement with the current status of knowledge and budget of time available. The tab as it is in its current status can be used to raise the awareness and to gain some insight into the effects of purchasing on the total footprint of the organization. However due to the large reduction of complexity, the results will not be as accurate as the other elements of the instrument. (This topic was discussed in a later stage and is described in Appendix D: Evaluation of the reliability of the instrument).

O.1 Produced electricity, heat or steam
HC: In addition to the comments as were already made for the block I.1 some remarks about the calculation of the environmental effect of steam. Based on the Dutch indicator 'bijstookfactor' the amounts of carbon emissions that need to be assigned to the produced heat are determined. (These suggestions were implemented and checked and approved by Croezen in sequence to this interview).

O.2 Transport of materials, products, waste and employees
HC: The calculations in this tab are based on trusted sources, the emission factors origin from reliable institutions. The routing between the different options needs to be improved.

O.3 Physical, chemical processing
HC: The absence of general calculations or approaches to map the carbon emissions and water usage of the production processes, chemical processes or for example agricultural processes is clear. The diversity of the production processes is too large to be simplified into general assumptions. Even between chemical processes with similar characteristics, the variation of the impact is too large to base assumptions on. This could result in 100's of % of deviation in case of the production of aluminum, as an example. If an organization that is subject of study contains this type of processes a tailor-made approach is necessary.

O.4 Fugitive emissions
HC: The same comment as given in tab O.3, this requires a tailor-made approach. In order to cover the agricultural sector it is very important to take the storage of manure and the natural processes in the intestines of the cattle. The other fugitive emissions in industrial processes are concerned with the same issues as mentioned in O.3.

O.5 Consumptive water use
HC: This calculation is performed correct. The information source that is defined is reliable; the metering of water withdrawal is certified and monitored to a high level. No further comments.

Ou.1 Use of sold products and services
HC: This category requires a tailor-made approach as was already mentioned at tab O.3. Besides this comments it can be disputed whether this part of the footprint is within the responsibility of the organization. The energy-labels which are available to determine the environmental impact of products during the use-phase are already indicating this. Since the impact is highly depending on the way of using the product, this lies beyond the responsibility of the organization.

Ou.2 Waste disposal
HC: The suggestion was made to contact Matthijs Otten, employee of CE Delft, who is an expert on the modeling of the impact of waste. This suggestion was followed and has resulted in adjustment to this tab.

Appendix B: Case study 1: Delft University of Technology

This document describes the case study that was carried out to test the instrument that was designed at a real case.

B.1 Goal

The goal of the case study is to test the instrument by applying it to a real case. For this pilot a complete footprint study will be performed that is aimed at determining the combined carbon and water footprint of Delft University of Technology. By reporting in detail the different steps and actions performed, the results achieved and the reflection on these topics, insight is created into the functioning of the instrument.

B.2 Approach

The instrument will be applied to determine the combined carbon and water footprint of Delft University of Technology. This pilot will be performed in several steps:

Define the organization
Determine the required input
Identify the sources for information
Gather data
Process data
Report results
These steps will guide the case study and allows the structured reporting of the progress

B.2.1 Define the organization

Delft University of Technology is located in Delft, province South-Holland in the Netherlands. The organization is aimed at performing research and providing education in the field of technical sciences. The university exists of 8 faculties, providing 14 Bachelor of Science and 38 Master of Science programs. In 2007 almost 14,300 students were enrolled in educational programs. In 2006 4433 people were employed at the University.

Figure 31 Map Delft University of Technology

The university is located on the TU Delft campus in Delft. There are eight faculty buildings, a central library, a conference centre, several laboratories, a cogeneration power plant, a reactor centre, sports & culture buildings and multiple supporting buildings for administration, ICT, shared service centers and educational facilities. The financial results of the university are presented in the figure below; not that the total result of the year 2008 is heavily influenced by the 100.8 million euros that were paid by the insurance company to the TU Delft after the fire in one of the faculty buildings. This transaction will be corrected in determining overall indicators.

	jaar								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Financiën									
Eigen vermogen (in M€)	157,6	159,3	165,3	163,6	182,3	204,1	222,6	222,7	289,9
Liquiditeitspositie (in M€)	13,7	-14,6	-15,7	22,5	63,9	69,9	77,8	74,5	49,7
Resultaat (in M€)	3,6	0,3	-4,2	-5,4	15,0	18,4	18,4	0,1	*69,4
1e geldstroom baten (in M€)	306,3	324,4	331,2	339,6	354,0	369,0	371,7	346,0	**369,3
Opbrengst werk derden (in M€)	65,8	65,6	75,9	70,4	79,7	82,7	97,7	105,9	129,8
Personeel bezoldigd									
Wetenschappelijk personeel (WP)	2401	2331	2332	2307	2334	2428	2613	2712	2762
Ondersteunend en beheerspersoneel (OBP)	2349	2381	2313	2245	2082	1775	1820	1859	1878
Verhouding WP:OBP	1,02	0,98	1,01	1,03	1,12	1,37	1,44	1,46	1,47
Gemiddelde leeftijd	39,9	40,4	40,8	41,1	41,3	40,2	39,8	39,8	39,9
Ziekteverzuim	-	-	3,8%	2,5%	3,0%	3,0%	2,7%	2,6%	2,6%

*) Het operationele resultaat van de TU Delft bedroeg in 2008 -€31,4 miljoen. Door de hoogte van de verzekeringsclaim van 118 miljoen, bedroeg het exploitatieresultaat van de brand bij Bouwkunde +€100,8 miljoen. Dit heeft het resultaat van de TU Delft in 2008 sterk positief beïnvloed.
**) De 1e geldstroom baten zijn in 2008 met € 25 miljoen toegenomen. Het betreft een incidentele Rijksbijdrage van het Ministerie van OCW voor de brand bij faculteit Bouwkunde.

Figure 32 Financial results Delft University of Technology (TU Delft, 2008)

The figures below show the amount of employees, measured in fulltime-equivalents that were employed at the TU Delft. These numbers are split up in scientific staff, teachers, professors, researchers and PhD's, and in supporting staff such as administrative staff.

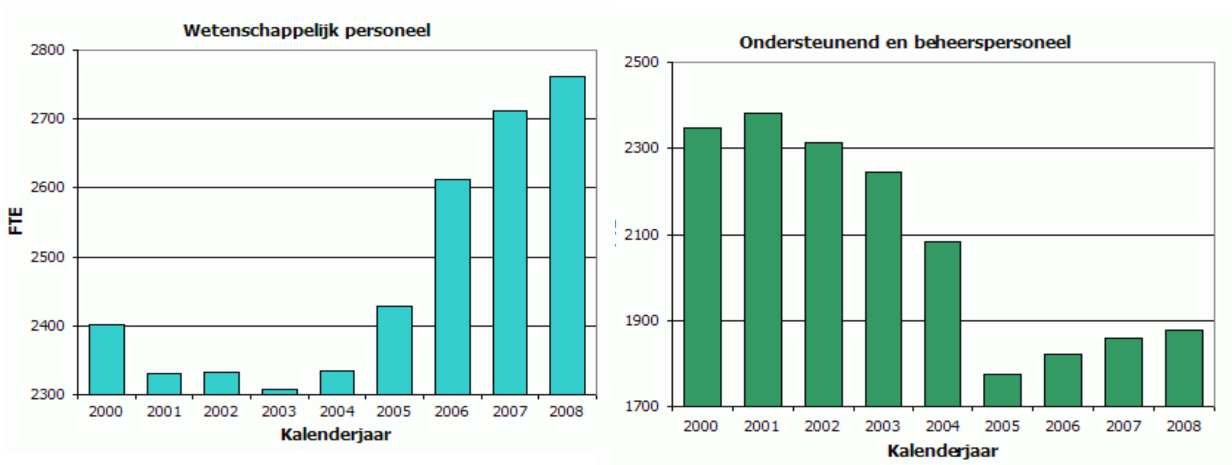


Figure 33 Number of employees TU Delft

In 2008 the number of employees was, 2780 scientific staff members and 1880 supporting staff members, adding up to 4660 employees.

The Delft University of Technology has been defined as the total of activities taking place in all university building at the TU Delft campus. These locations are providing room for all 4660 employees and the 14,300 students enrolled to the university. It is this definition of the Delft University of Technology that is used to define the organization of which the combined carbon and water footprint will be determined.

B.2.2 Determine the required input

To calculate the combined carbon and water footprint of the TU Delft, specific information on the sources of carbon emissions and water consumption is needed. Before data sources can be identified for data collecting, it is necessary to identify the different elements of the conceptual model that are applicable to this organization. To acquire insight into the relevant sources of the TU Delft, personal communication was arranged with employees concerned with facility management and real estate. Different conversations with experts in real estate, energy and environmental issues identified the relevance of the sources.

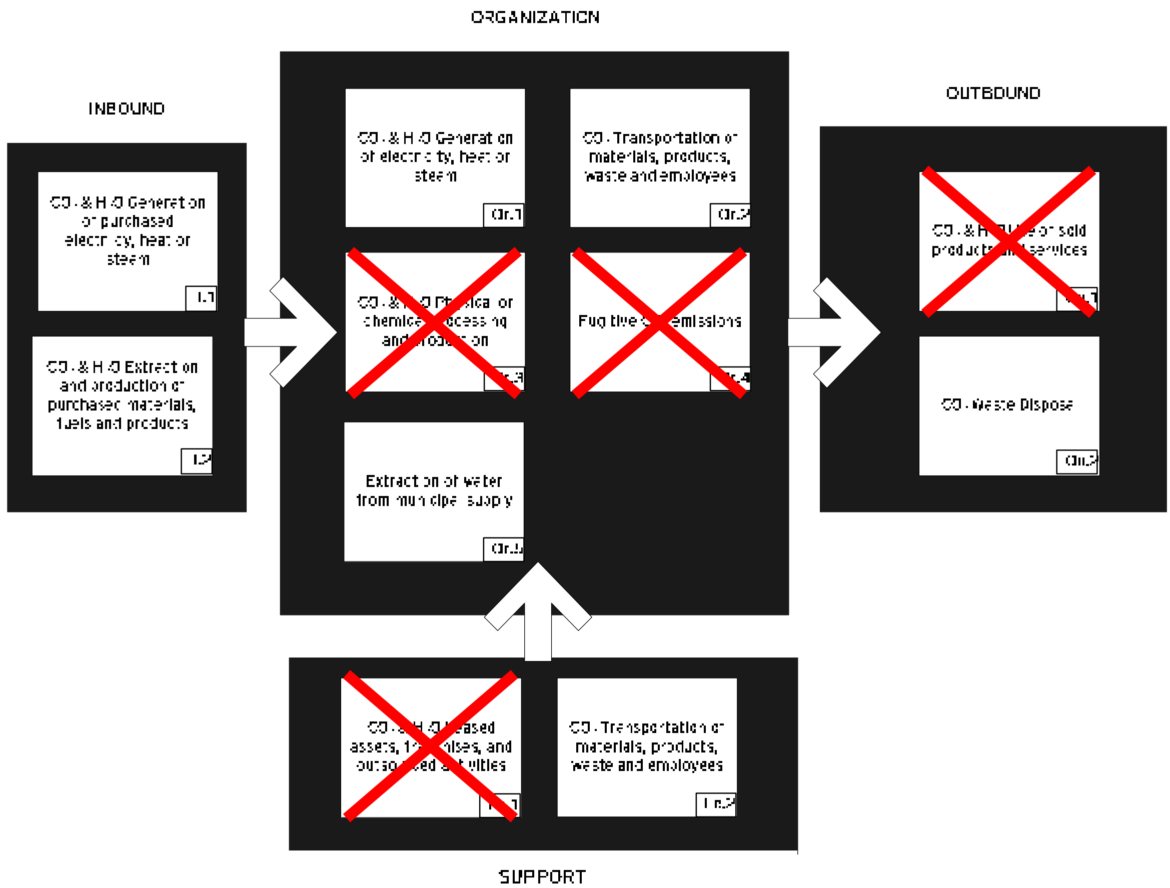


Figure 34 Relevant sources of carbon emissions and freshwater usage TU Delft

The physical or chemical processing and production block was not found relevant for TU Delft. The experts claimed that the largest amount of emissions occurred due to the combustion of natural gas for heating during scientific tests or educational exercises in laboratories. Also the energy needed to power the electrical equipment is taken into account in the purchased electricity block. The fugitive emissions due to leakages of equipment or intentional gas releases were excluded based on two reasons. The expected amount of emissions in this category was very low and the ability to acquire this information was expected to be very difficult. Due to these expectations this block was also excluded. The block with the use of sold products and services was also left out of the case study. No real products or services could be identified that would contribute to the size of the footprint during their 'use-phase'. Also the category leased assets, franchises and outsourced activities was left out, this category was also not found relevant by the experts.

Based on the selected blocks, the information sources that contain the necessary information can be identified and localized within the organization.

Required input & Data sources Pilot Delft University of Technology		
Year: 01/01/08 - 31/12/08		
I.1. Generation of purchased electricity, heat or steam		
Purchased electricity	Supplier	Usage (kWh)
Purchased heat	Supplier	Usage (MW)
Source: FMVG Energy (W.H. van Rijsbergen)		
I.2. Extraction and production of purchased materials, fuels and products		
Purchased raw materials	Type	Usage (kg)
Purchased half-fabricates	Type	Usage (kg)
Purchased products	Type	Usage (kg)
Source: Finance & Control (B. Minnella) / FMVG Environment (W.H. van Rijsbergen)		
Or.1. Production of electricity, heat or steam		
Electricity production	FuelMix	Production (kWh)
Heat production	Natural Gas Usage (m3)	
Source: FMVG Energy (W.H. van Rijsbergen)		
Or.2. Transport of materials, employees, products and waste		
Travelled miles in owned vehicles	Type	Milage (km)
Source: Finance & Control (B. Minnella)		
Or.5. Extraction of water from municipal supply		
Extraction of water	Consumption (l)	
Source: FMVG Environment (G. van Schaik)		
Le.2. Transportation of materials, employees, products and waste		
Travelled miles in leased vehicles	Type	Milage (km)
Source: Finance & Control (B. Minnella)		
Ou.2 Waste Disposal		
Disposal of waste	Type	Amount (ton)
Source: FMVG Environment (G. van Schaik)		

Figure 35 Required input & data sources Pilot Delft University of Technology

B.2.3 Data gathering

The necessary information is collected by contacting the head of the facility management of the TU Delft. By asking him the type of information that was necessary to perform the footprint study, he has provided the names and contact information of the employees within the TU Delft. After this personal communication the three important departments and contact persons were identified. Three departments needed to be contacted to acquire the necessary information. The department of Facility Management and Real Estate, FMRE (FMVG in Dutch), is responsible for all facilities and real estate of the TU Delft. The department FMRE Energy is concerned with all energy related matters. FMRE Environment is responsible for all matters concerning the environment including purchase of products and waste disposal. Finance & Control is the department that takes care of the financial administration of the TU Delft; this includes information of all monetary transactions.

The interactions with the contact-persons efficiently resulted into the necessary information. This information is included at the end of this appendix.

Required input & Data sources Pilot Delft University of Technology	**Results:**	
Year: 01/01/08 - 31/12/08		
I.1. Generation of purchased electricity, heat or steam		
Purchased electricity	Acquired all data (kWh)	67.376.412,00
Purchased heat	Not relevant	0
I.2. Extraction and production of purchased materials, fuels and products		
Amount spent per category of industry	Acquired part of data	
	• expenses on electrical equipments	€ 3.142.411,25
	• expenses on furniture	€ 8.556.779,61
	• expenses on other equipments	€ 10.102.314,22
Or.1. Production of electricity, heat or steam		
Electricity production (fuelmix and amount)	Acquired all data (m3 Natural gas)	1.084.001,00
Heat production	Acquired all data (m3 Natural gas)	8.615.259,32
Or.2. Transport of materials, employees, products and waste		
Travelled miles in owned vehicles	Not relevant	0
Or.5. Extraction of water from municipal supply		
Extraction of water	Acquired all data (liter)	221.511.000,00
Le.2. Transportation of materials, employees, products and waste		
Travelled miles in leased vehicles	Acquired part of data	
	• road kilometers (spent on)	€ 494.791,00
	• air kilometers (spent on)	€ 8.994.857,00
	• public transportation (spent on)	€ 1.700.969,00
Ou.2 Waste Disposal		
Disposal of waste	Acquired all data (tons Residual waste)	32,19
	(tons Paper and Cardboard)	324,56
	(tons Glass)	8,61
	(tons Metal)	135,66

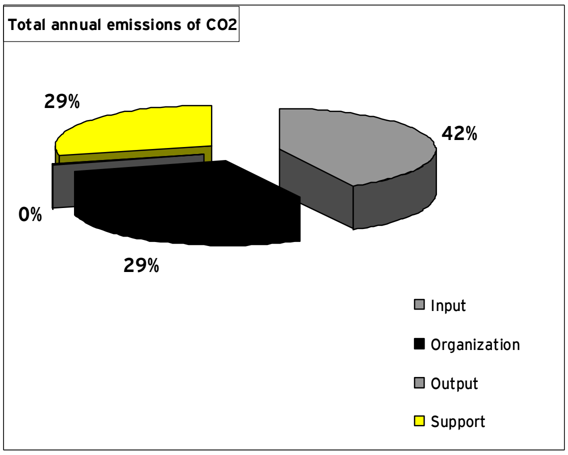
Figure 36 Gathered data Pilot TU Delft

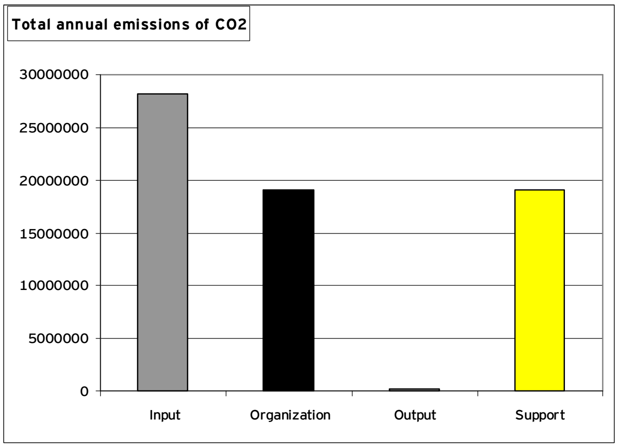
B.2.4 Report results

The results of the combined carbon and water footprint study are represented in the figures below. The total amount of carbon emissions due to the activities performed by the Delft University of Technology are 66.490 tons of carbon dioxide equivalents. The total amount of freshwater usage was 342.788 m3 of freshwater.

Total CO2 emissions / year	66.490.047,54	kg CO2
Total water usage / year	342.788.550,60	liter water

The emissions per organization category show the main drivers of the carbon footprint. In thed case the input and support part account for 1/3 each, and the other 40 percent is caused by the input part of the organization.

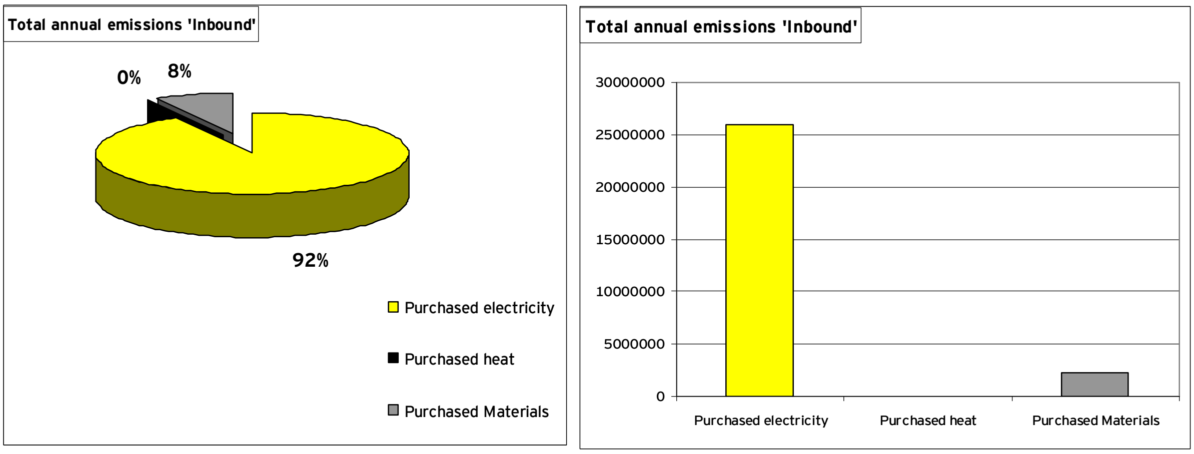




Input	28144477,32	kg CO2/year	42,33%
Organization	19042687,04	kg CO2/year	28,64%
Output	217077,48	kg CO2/year	0,33%
Support	19085805,7	kg CO2/year	28,70%
Total:	66490047,54	kg CO2/year	100,00%

Figure 37 Total annual emissions TU Delft percentage by category

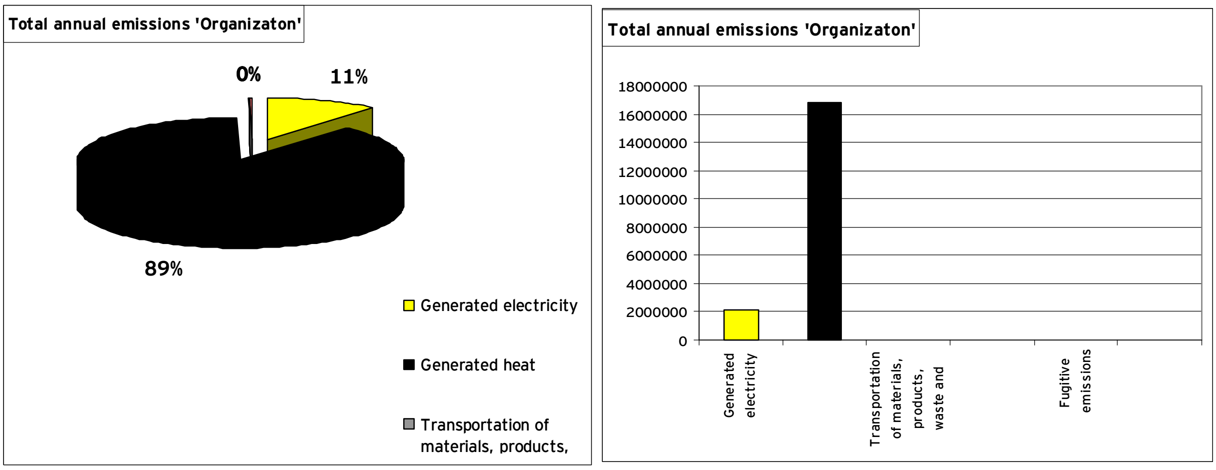
To identify the main causes of the size of the carbon footprint of the Delft University of Technology, the three categories, input, organization and support need to be analyzed further. The category 'Output' which consist for 100% of the emissions due to the Disposal of Waste, contributes only 0,33% of the total carbon emissions and is therefore not analyze into further detail.



Purchased electricity	25872544,13	kg CO2/year	91,93%
Purchased heat	0	kg CO2/year	0,00%
Purchased Materials	2271933,19	kg CO2/year	8,07%
Total:	28144477,32	kg CO2/year	100,00%

Figure 38 Total carbon emissions TU Delft, category 'Inbound'

The purchased electricity is the largest part of the 'inbound' emissions category. The purchase of materials, fuels and products account for only 8% of the total emissions. The purchased electricity is produced by Eneco and in total TU Delft bought and used 67.376.417 kWh of electricity to support its activities.



Generated electricity	2124641,96	kg CO2/year	11,16%
Generated heat	16885908,26	kg CO2/year	88,67%
Transportation of materials, products, waste and employees	0,00	kg CO2/year	0,00%
Physical, chemical production processes	0,00	kg CO2/year	0,00%
Fugitive emissions	0,00	kg CO2/year	0,00%
Consumptive Water extraction	32136,82	kg CO2/year	0,17%
Total:	19042687,04	kg CO2/year	100,00%

Figure 39 Total carbon emissions TU Delft, category 'Organization'

In the category 'organization' the largest amount of carbon emissions is caused by the generation of heat. TU Delft heats its buildings in two ways. The first is the regular usage of natural gas that is burned to increase the temperature of buildings. Beside this TU Delft has a co-generation plant that produces both electricity and heat. The combined figure of Production of heat, is the largest source of emissions in this category.

Leased assets / outsourced activities	0,00	kg CO2/year	0,00%
Transportation of materials, products, waste and employees	19085805,70	kg CO2/year	100,00%
Total:	19085805,70	kg CO2/year	100,00%

Figure 40 Total carbon emissions TU Delft, category Support

The last category, support, consists of 100% transport related emisisons. This category was built up from the information on travel expenses on air-traffic and public transportation within the Netherlands.

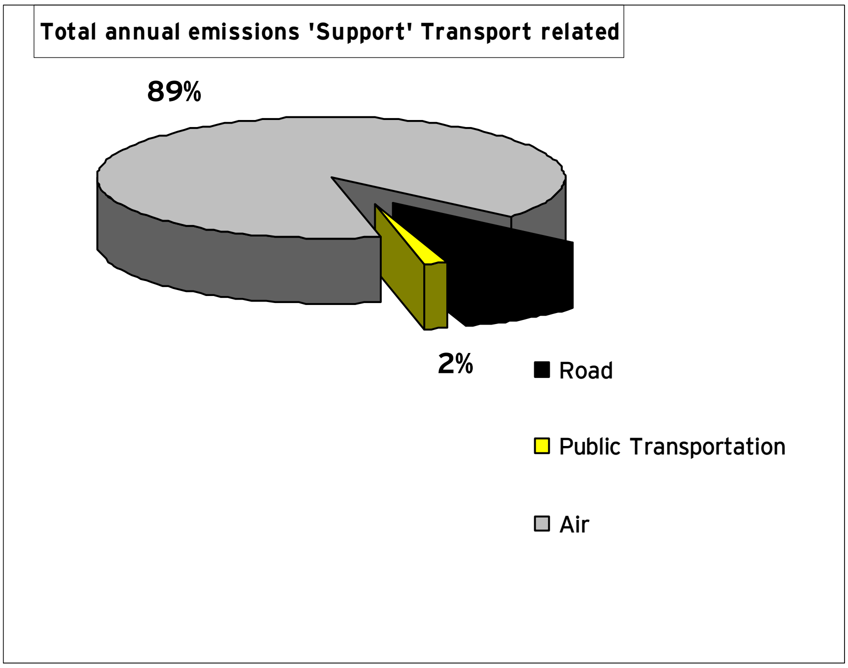
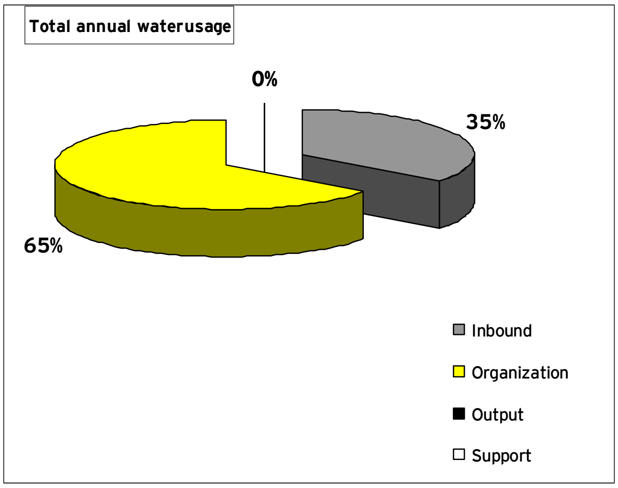


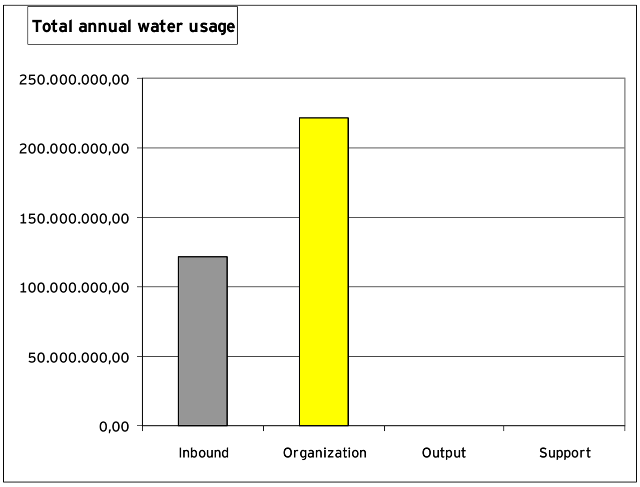
Figure 41 Total emissions TU Delft, category Support - Transport related emissions

Road	1.672.393,85	kg CO2	8,76%
Public Transportation	323.184,19	kg CO2	1,69%
Air	17.090.227,65	kg CO2	89,54%
Total:	19.085.805,70	kg CO2	100,00%

The results clearly show that the largest part of the carbon emissions originate from the usage of air traffic. The public transport only accounts for a small part of the emissions and the road transport slightly more, but with les than 9% not large.

The results from the calculation show the main causes of carbon emissions and clearly identify the main drivers.

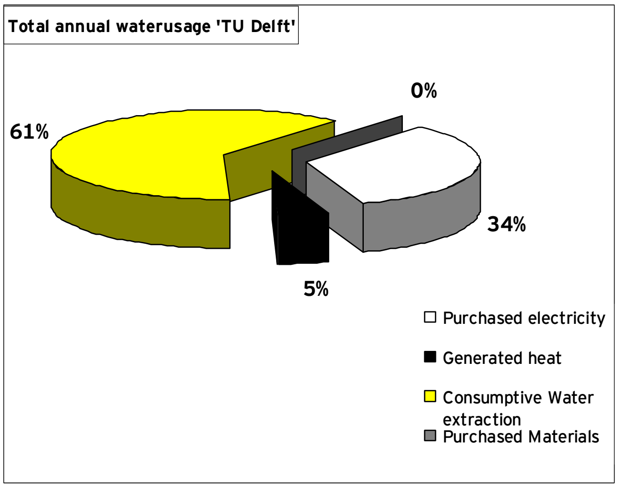


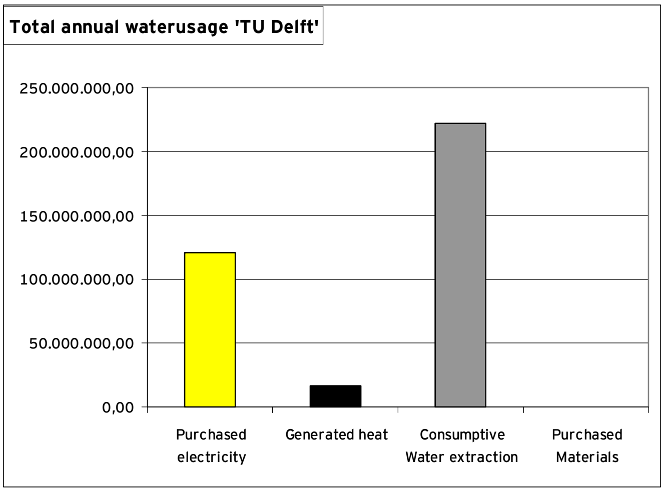


Inbound	121.277.550,60	kg CO2/year	35,38%
Organization	221.511.000,00	kg CO2/year	64,62%
Output	0,00	kg CO2/year	0,00%
Support	0,00	kg CO2/year	0,00%
Total:	342.788.550,60	kg CO2/year	100,00%

Figure 42 Total annual water usage TU Delft, per category

The total annual water usage of the TU Delft is 342.788 m3 of freshwater. The inbound and organization categories are the main component causing the water usage.





Purchased electricity	121.277.550,60	liter water / year	33,72%
Generated heat	16.885.908,26	liter water / year	4,69%
Consumptive Water extraction	221.511.000,00	liter water / year	61,59%
Purchased Materials	384.220,11	liter water / year	0,11%
Total:	359.674.458,86	liter water / year	100,00%

Figure 43 Total annual water usage TU Delft, all sources

This overview shows all sources of water usage of the TU Delft and their relative an actual values. It is clear that the direct water consumption from the municipal supply is the largest part of the footprint with 61%. The generated heat consumes water due to the water that was used during the extraction and production of the natural gaz. The water used for the producing the purchased electricity was used in the cooling towers.

B.2.5. Comparable results

To be able to compare the outcomes of the calculations the results are calculated into well interpretable and comparable figures. Important notion to the comparing of results must be made. The outcomes are fully depending on the information as was provided by the organization. Before these results are compared to any other organization, it must be determined whether the organizations have provided the information within the same scopes. If the conceptual model is fully adopted and all information within the element is gathered, then the results are fit for comparison without doubts. Otherwise the different element of the organization can be compared, for example by taking the result of the 'organization' tab only. Also the reporting scopes as defined by the GHG are fit to overcome comparison problems, this could be used to avoid comparison issues of the carbon results.

General information		
Name of organization:	TU Delft	
Time period of study:	01-01-2008 / 31-12-2008	
Characteristics of organization		
Total number of employees (fte's)	4.433,00	fte
Total annual profit	69.400.000,00	Euro
Total annual carbon emissions / employee	15,00	tonCO2/employee/year
Total annual water consumption / employee	77,33	m3Water/employee/year
Total annual carbon emissions / profit	0,9580698	kgCO2/euro/year
Total annual water consumption / profit	4,9393163	lWater/euro/year

	For comparison:	
Total carbon emissions	66.490.047,54	kg
Total carbon emissions / employee	14998,88	kg
	Equals to:	
Total carbon emisssions	192.167.767,45	km in Hummer H3 3.7 AUT
Total carbon emissions / employee	43.349,37	km in Hummer H3 3.7 AUT
	Equals to:	
Total carbon emisisons	22.045,77	retour-flights Amsterdam-Sydney
Total carbon emissions / employee	4,97	retour-flights Amsterdam-Sydney
	Equals to:	
Total carbon emisisons	426.218,25	retour-flights Amsterdam-London
Total carbon emissions / employee	96,15	retour-flights Amsterdam-London

Figure 44 Results case study TU Delft, Comparable indicators

B.2.6. Log of contacts

Log of contacts case-study Delft University of Technology			Total duration: 130 minutes
Name of contact:	E. de Vos		
Function:	manager		
Department:	Facility Management, faculty TPM		
Date:	Type:	Content:	Duration:
10-7-2009	phonecall	Introduction of topic Redirecting to different contactpersons	15 minutes
10-7-2009	phonecall	Clarifying some extra questions of who to contact Information: Securicor uses Renault Kangoo Diesel, drives from mo-fr from 23-7 over the TU terrain and sa-su 24h per day over ther TU terrain	5 minutes
Name of contact:	W.H. van Rijsbergen		
Function:	Head of department		
Department:	FMRE Energy		
Date:	Type:	Content:	Duration:
10-7-2009	phonecall	Introduction of topic Wil states he has all the information on: elektricity, purchase and production purchase of natural gas agreement to send information based on request	15 minutes
22-7-2009	e-mail	Information request	15 minutes
24-7-2009	e-mail	Information received	
Name of contact:	G. van Schaik		
Function:	Head of department		
Department:	FMRE Environment		
Date:	Type:	Content:	Duration:
10-7-2009	phonecall	Introduction of topic Gerrit states he has all the information on: purchased products, (chemicals) disposal of waste (per category) agreement to send information based on request	15 minutes
22-7-2009	e-mail	Information request	15 minutes
24-7-2009	e-mail	Information received	
4-8-2009	e-mail	Extra information asked	5 minutes

4-8-2009	e-mail	Extra information received	
Name of contact:	B. Minella		
Function:	Controller		
Department:	Finance & Control		
Date:	Type:	Content:	Duration:
28-7-2009	phonecall	Introductin of topic	
		Bennito states he has the information on :	
		expenditures on travelling	
		expenditures on purchased materials	
		agreement to visit and look for information	15 minutes
29-7-2009	meeting	look for information	
		send information in digital format	30 minutes

Figure 45 Log of contacts and duration TU Delft

B.3 Results

The case study as has been performed at Delft University of Technology was aimed at testing the instrument in a real life situation to evaluate its performance. During the case study several important results were gathered. Besides the insight into the carbon and water footprint of the organization it also resulted in insight into the functioning of the instrument.

Gathering data at the TU Delft was supported by the employees and the existing information systems to a large extent. Due to the excellent and detailed information systems that are used, the required information could be obtained rather easily. This was for all information relating to electricity, heat, waste, purchased goods, materials and products. The data on the traveled kilometers was only available in the monetary units. Declarations of the traveled miles results into payments, which are registered in the financial administration. Translating the financial information into the environmental impact introduces errors into the calculations (see Appendix D). It is advised for future data gathering and calculations to be made, that the administration is improved into more detail.

Appendix C: Case study 2: Ernst & Young Netherlands

This document describes the case study that was carried out to test the instrument that was designed at a real case. This is part of the evaluation of the instrument based on the stated requirements.

C.1 Goal

The goal of the case study is to test the instrument by applying it to a real case. For this pilot the combined carbon and water footprint of Ernst & Young in the Netherlands is calculated. This pilot is realized by complying with the initiative of EY Global, to calculate the carbon footprint of the entire organization. The focus of this initiative was on the carbon footprint and less on the water footprint. Although the effort was put in gathering data that allowed calculating the combined footprint, main focus was on the carbon. Still the pilot is useful to test the requirements as stated by the future user of the instrument.

C.2 Approach

The instrument will be applied to determine the combined carbon and water footprint of Ernst & Young the Netherlands. This pilot will be performed in several steps:

Define the organization
Determine the required input
Identify the sources for information
Gather data
Process data
Report results

These steps will guide the case study and allows the structured reporting of the progress.

C.2.1 Define the organization

Ernst & Young the Netherlands is part of the global Ernst & Young (EY) organization that employs 140.000 people globally. It is one of the largest professional services firms in the world, and part of the 'big four auditors' together with PriceWaterhouseCoopers, Deloitte and KPMG. EY provides assurance, tax, transaction and advisory services. The global headquarter is located in London, UK, the US firm is headquartered in New York, and the Dutch headquarters is located in Rotterdam.

Revenue

By Service Line US$ millions	FY08	FY07	% change US$	% change local currency
Assurance & Advisory Business Services	16,599	14,530	14.2	7.8
Tax	6,744	5,566	21.2	14.2
Transaction Advisory Services	2,946	2,463	19.6	13.0
Less elimination*	-1,766	-1,455	n/a	n/a
Total	24,523	21,104	16.2	9.5

* For management reporting purposes certain revenues are included in multiple Service Lines and have been eliminated in presenting total revenue.

By Area US$ millions	FY08	FY07	% change US$	% change local currency
Americas	9,820	9,019	8.9	7.1
EMEIA	11,408	9,632	18.4	7.9
Far East	1,252	946	32.3	25.8
Oceania	1,009	782	29.0	14.9
Japan	1,034	725	42.6	31.1
Total	24,523	21,104	16.2	9.5

Figure 46 Ernst & Young Revenue 2007/2008 by service line (E&Y, 2008)

E&Y in the Netherlands has 27 offices located throughout the Netherlands, spread over the cities of Alkmaar, Amersfoort, Amsterdam, Breda, Arnhem, Den Bosch, Den Haag, Ede, Eindhoven, Emmen, Hazerswoude, Groningen, Hengelo, Leeuwarden, Leiden, Maastricht, Naaldwijk, Nijmegen, Roermond, Rotterdam, Terneuzen, Utrecht and Zwolle. In the Netherlands a total of 4,617 people are employed within Ernst & Young, this includes all staff from partners to supporting staff.

C.2.2 Determine the required input

To calculate the combined carbon and water footprint of EY the Netherlands, specific information on the sources of carbon emissions and water consumption is needed. Before data sources can be identified for data collecting, it is necessary to identify the different elements of the conceptual model that are applicable to this organization. To acquire insight into the relevant sources of EY the Netherlands, personal communication was arranged with a director of the EY Knowlegde Centre Corporate Social Responsibility, who has large experience and authority within this field of knowledge.

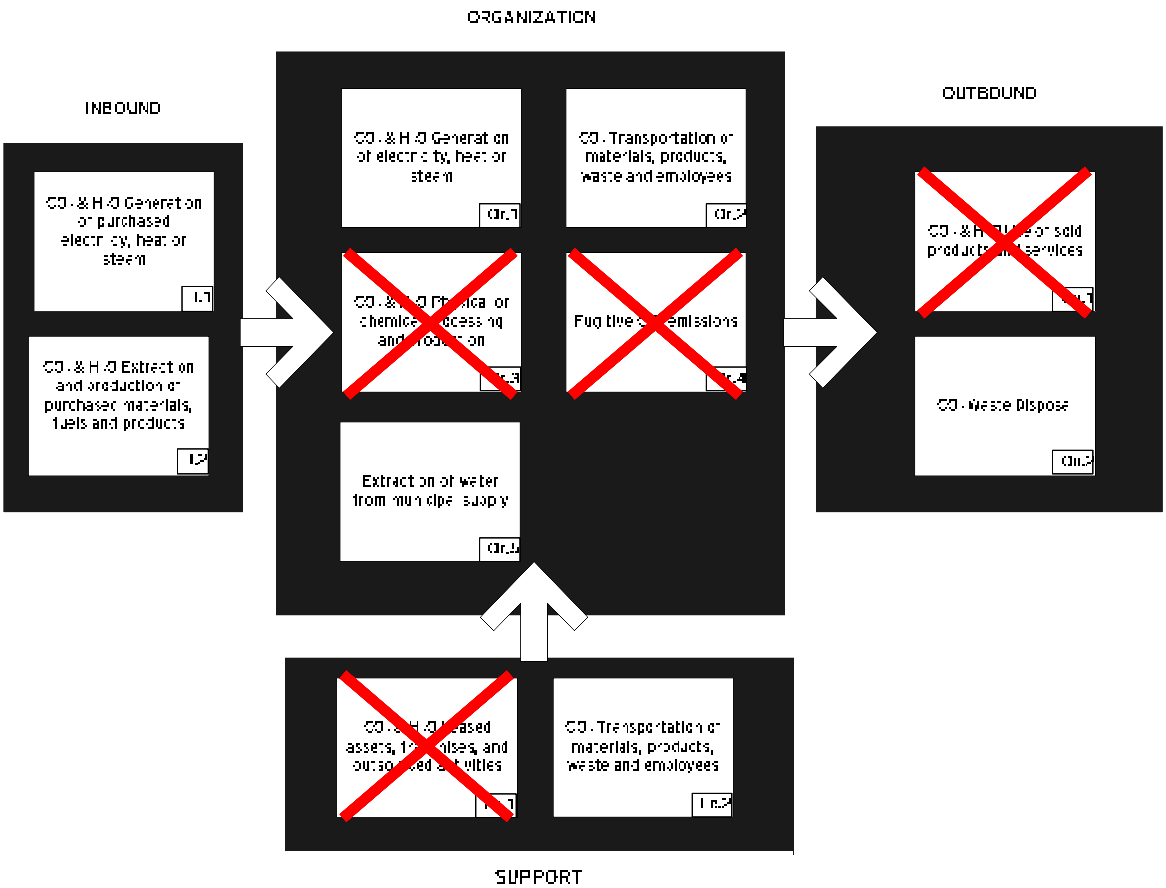


Figure 47 Relevant sources of carbon emissions and freshwater usage Ernst & Young the Netherlands

Main focus of the footprint study within EY was on the transportation and housing, including the electricity usage, of the staff members. It is expected that these sources will be responsible for the largest part of the carbon and water footprint of the organization. The inbound block, including the purchased electricity and the purchased materials and products are taken into account. In the organization block, the physical and chemical processing and the fugitive emissions are left out of the analysis. This because, as a result of the personal communication with the director, no physical or chemical processes are present within EY the Netherlands, and the fugitive emissions also don't play an important role. The support block does not include the leased assets or franchises, all effects from the buildings, owned or hired, are already taken into account in the organization part. Finally in the outbound block the use of sold products and services are not taken into account as separate group. EY sells no products but services, the emissions due to these services are taken into account by the rest of the analysis.

Based on the selected blocks, the information sources that contain the necessary information can be identified and localized within the organization.

Required input & Data sources Pilot Ernst & Young the Netherlands		
Year: 01/01/08 - 31/12/08		
I.1. Generation of purchased electricity, heat or steam		
Purchased electricity	Supplier	Usage (kWh)
Purchased heat	Supplier	Usage (MW)
I.2. Extraction and production of purchased materials, fuels and products		
Purchased raw materials	Type	Usage (kg)
Purchased half-fabricates	Type	Usage (kg)
Purchased products	Type	Usage (kg)
Or.2. Transport of materials, employees, products and waste		
Traveled miles in owned vehicles	Type	Mileage (km)
Or.5. Extraction of water from municipal supply		
Extraction of water	Consumption (l)	
Le.2. Transportation of materials, employees, products and waste		
Traveled miles in leased vehicles	Type	Mileage (km)
Ou.2 Waste Disposal		
Disposal of waste	Type	Amount (ton)

Figure 48 Required input & data sources Pilot Ernst & Young, the Netherlands

C.2.3 Data gathering

The gathering of data was coordinated by the earlier mentioned director of the Corporate Sustainability Knowledge Center. By identifying the relevant sources and the different contact persons within the organization, this process was streamlined. The department of Procurement & Services, responsible for all purchasing activities within EY the Netherlands, was found as the main source of information. The information on the waste disposal was directly obtained from the responsible waste-processing corporation. Not al the information that was required could be acquired during the case study, more reflection on this can be found in C. 3 Results.

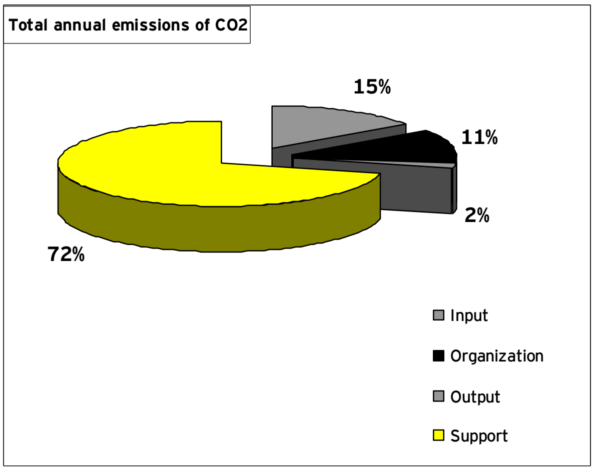
To be able to compare the outcomes of the calculations the results are calculated into well interpretable and comparable figures. Important notion to the comparing of results must be made. The outcomes are fully depending on the information as was provided by the organization. Before these results are compared to any other organization, it must be determined whether the organizations have provided the information within the same scopes. If the conceptual model is fully adopted and all information within the element is gathered, then the results are fit for comparison without doubts. Otherwise the different element of the organization can be compared, for example by taking the result of the 'organization' tab only. Also the reporting scopes as defined by the GHG are fit to overcome comparison problems, this could be used to avoid comparison issues of the carbon results.

C.2.4 Report results

The results of the combined carbon and water footprint study are represented in the figures below. The total amount of carbon emissions due to the activities performed by Ernst & Young are tons of carbon dioxide equivalents. The total amount of freshwater usage was m3 of freshwater.

Total CO2 emissions / year		kg CO2
Total water usage / year		liter water

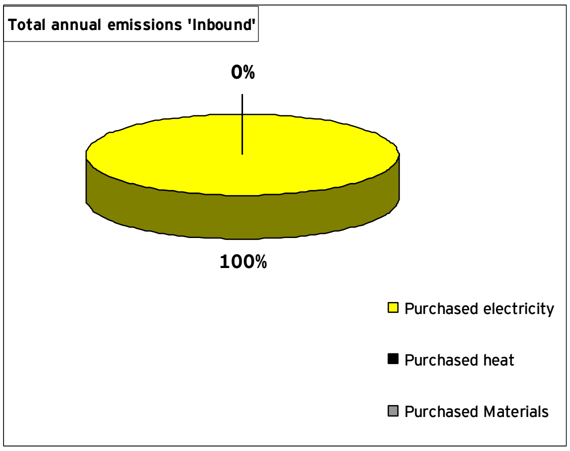
The emissions per organization category show the main drivers of the carbon footprint. In this case the support category is the largest category, over 70%. The Input and Organization category are 10% and 15%, very small amount of emissions is caused by the output of the organization, in this case waste.



Input	kg CO2/year	15,21%
Organization	kg CO2/year	11,44%
Output	kg CO2/year	2,10%
Support	kg CO2/year	71,25%
Total:	kg CO2/year	100,00%

Figure 49 Total annual emissions Ernst & Young percentage by category

To identify the main causes of the size of the carbon footprint of Ernst & Young the three categories, input, organization and support need to be analyzed further. The category 'Output' which consist for 100% of the emissions due to the Disposal of Waste, contributes only 2% of the total carbon emissions and is therefore not analyze into further detail.



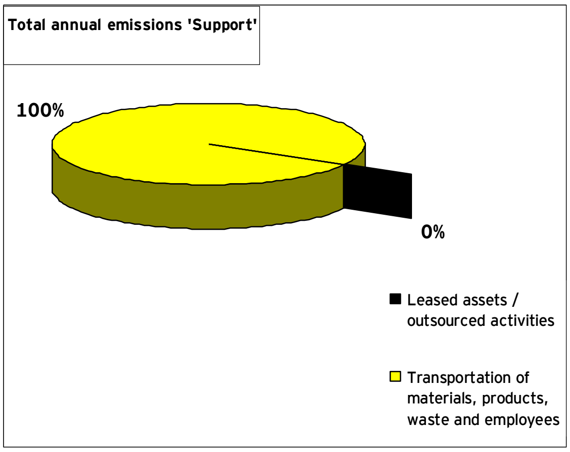
Purchased electricity	kg CO2/year	100,00%
Purchased heat	kg CO2/year	0,00%
Purchased materials	kg CO2/year	0,00%
Total:	kg CO2/year	100,00%

Figure 50 Total carbon emissions Ernst & Young, category 'Inbound'

The purchased electricity is the only and thereby largest part of the 'inbound' emissions category. The purchase of heat is not relevant due to the fact that Ernst & Young does not purchase heat in its offices, but produces this by the combustion of natural gas. The category of purchased materials, products and goods has not been filled in. Due to time constraints this information was not available.

Figure 51 Total carbon emissions Ernst & Young, category 'Organization'

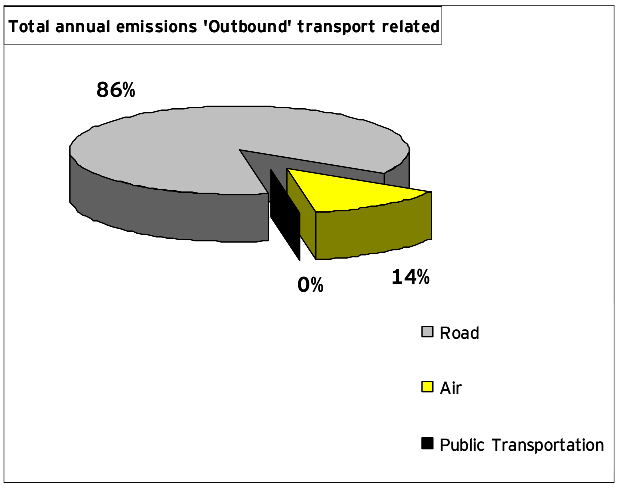
In the category 'organization' the largest amount of carbon emissions is caused by the generation of heat. Only a marginal percentage of the carbon emissions results from the extraction of drinking water from the municipal supply. The heating of buildings is the primary factor in this part of the footprint.



Leased assets / outsourced activities	kg CO2/year	0,00%
Transportation of materials, products, waste and employees	kg CO2/year	100,00%
Total:	kg CO2/year	100,00%

Figure 52 Total carbon emissions Ernst & Young, category Support

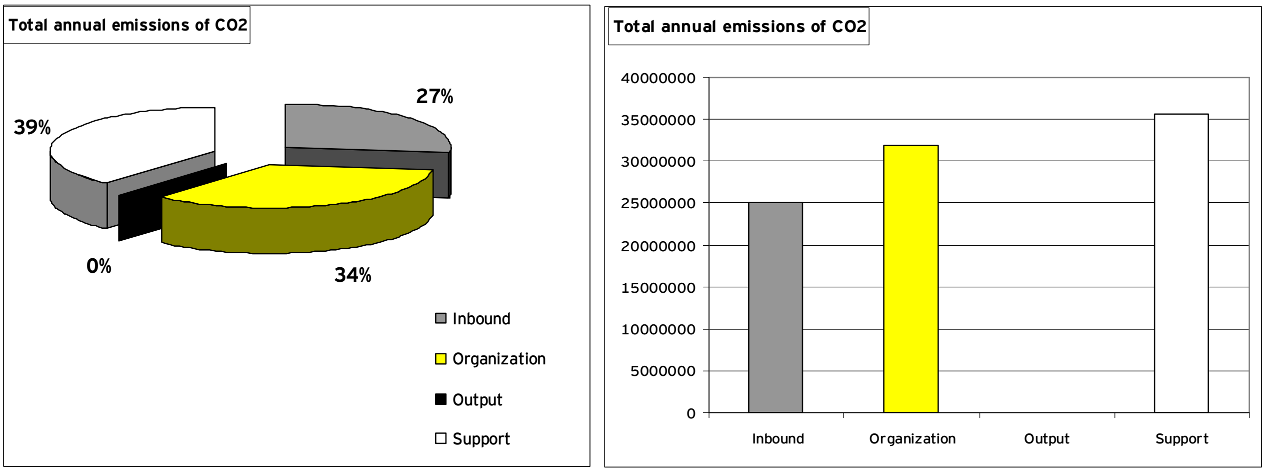
The last category, support, consists of 100% transport related emissions. This category was built up from the information on the mileages of leased cars, of the partner cars, and of the flight kilometers as registered in the systems. The information on public transportation could not be acquired within the limited time, and therefore is not present in this output.



Road	kg CO2/year	86,29%
Air	kg CO2/year	13,71%
Public Transportation	kg CO2/year	0,00%
Total	kg CO2/year	100,00%

Figure 53 Total emissions Ernst & Young, category Support - Transport related emissions

The results clearly show that the largest part of the carbon emissions originate from the usage of road based vehicles.



Inbound	l water / year	27,06%
Organization	l water / year	34,40%
Output	l water / year	0,00%
Support	l water / year	38,54%
Total:	l water / year	100,00%

Figure 54 Total annual water usage Ernst & Young, per category

The total annual water usage of Ernst & Young is XXX m3 of freshwater. The categories of Inbound, Organization and Support account for almost a third of the total water usage.

Figure 55 Total annual water usage TU Delft, all sources

This overview shows all sources of water usage of Ernst & Young and their relative and actual values. It is clear that the categories of direct water extraction, production of purchased electricity and the water usage due to the production of the fossil fuels used in transportation of materials, products and employees are similar sizes.

Log of contacts case-study Ernst & Young the Netherlands			Total duration: 115 minutes
Name of contact: Function: Department:			
Date:	Type:	Content:	Duration:
21-7-2009	conference call	Introduction of topic Setting up plan	60 minutes
21-7-2009	e-mail	Identifying required information	30 minutes
23-7-2009	e-mail	Proposal required information	5 minutes
27-7-2009	e-mail	Adjustment required information	5 minutes
between 30-07-2009 and 05-08-2009	several phonecalls	Updates on information sources	
Name of contact: Function: Department:			
Date:	Type:	Content:	Duration:
4-8-2009	e-mail	Ask for names of contact persons	5 minutes
4-8-2009	e-mail	Received information Additional information, due dates of information Problems in acquiring data, possible other approaches	10 minutes

Figure 56 Log of contacts and duration E&Y

C.2.5. Comparable results

To be able to compare the outcomes of the calculations the results are calculated into well interpretable and comparable figures. Important notion to the comparing of results must be made. The outcomes are fully depending on the information as was provided by the organization. Before these results are compared to any other organization, it must be determined whether the organizations have provided the information within the same scopes. If the conceptual model is fully adopted and all information within the element is gathered, then the results are fit for comparison without doubts. Otherwise the different elements of the organization can be compared, for example by taking the result of the 'organization' tab only. Also the reporting scopes as defined by the GHG are fit to overcome comparison problems, this could be used to avoid comparison issues of the carbon results.

Total:		
Total CO2 emissions / year		kg CO2
Total water usage / year		liter water
General information		
Name of organization:	Ernst & Young The Netherlands	
Time period of study:	01-01-2008 / 31-12-2008	
Characteristics of organization		
Total number of employees (fte's)	4.617,00	fte
Total annual profit (2008)	24.523.000,00	Euro
Total annual carbon emissions / employee		tonCO2/employee/year
Total annual water consumption / employee		m3Water/employee/year
Total annual carbon emissions / profit		kgCO2/euro/year
Total annual water consumption / profit		lWater/euro/year
	For comparison:	
Total carbon emissions		kg
Total carbon emissions / employee		kg
	Equals to:	
Total carbon emisssions		km in Hummer H3 3.7 AUT
Total carbon emissions / employee		km in Hummer H3 3.7 AUT
	Equals to:	
Total carbon emisisons		retour-flights Amsterdam-Sydney
Total carbon emissions / employee		retour-flights Amsterdam-Sydney
	Equals to:	
Total carbon emisisons		retour-flights Amsterdam-London
Total carbon emissions / employee		retour-flights Amsterdam-London

Figure 57 Results case study TU Delft, Comparable indicators

C. 3 Results

The case study as has been performed at Ernst & Young the Netherlands was aimed at testing the instrument in a real life situation to evaluate its performance. During the case study several important results were gathered. Besides the insight into the carbon and water footprint of the organization it also resulted in insight into the functioning of the instrument.

Gathering the required data for this case study was a bottleneck for the analysis. Within the framework of time as was established for this part of the master thesis research, not all the data could be delivered. The data on the purchased goods, products and materials could not be acquired this information was not readily available in the information systems. The information on the public transportation also could not be found, the responsible person for this part was unable to gather this data on time. The information on the disposal of waste was obtained from the waste-processing organization directly. Although this was a very relevant information source, not all the offices of Ernst & Young are under contract with the same organization. Therefore solely the data on the offices that were serviced by van Gansewinkel could be found. It is expected that this information is available in the systems of the organization, and that extra investment of time would result in successful data collection.

The missing data in this case study influences the results of the analysis. Without the additional information the results of the analysis using the instrument will not produce relevant information for gaining insight into the actual carbon and water footprint of the organization.

Appendix D: Evaluation of the reliability of the instrument

The reliability of the results of the instrument is a critical factor in determining the value of the instrument. Preferred method to check the reliability of the calculations would be to compare the outcomes of this instrument to check the reliability. Since the developed instrument is unique in its ability to calculate the combined carbon and water footprint of an organization, it is not possible to compare the calculations to other instruments. To overcome this problem, the reliability of the instrument is not checked as a whole, but the different calculations in the model are discussed separately. This is assumed to be a valid check since the total result is determined by the sum of the separate calculations.

This check was performed in co-operation with drs. Harry Croezen expert from CE Delft. After the interview an additional discussion with him was held and resulted in the approval of the analysis as reported in this appendix.

Category	Range of error
Inbound	
I.1 Purchased electricity, heat or steam	< 5% - 10%
I.2 Purchased products, goods, materals	< 50%
Organizations	
O.1 Production of electricity, heat or steam	< 5% - 10%
O.2 Transport of materials, products, waste and employees	<20%
O.3 Physcial or chemical processing	n.a.
O.4 Fugitive emisisons	n.a.
O.5 Consumptive water usage	< 5% - 10%
Outbound	
Ou.1 Use of sold products and services	n.a.
Ou.2 Waste disposal	< 20%
Support	
Le.1 Leased assets, outsourced activities	n.a.
Le.2 Transport of materials, products, waste and employees	<20%

Figure 18Figure 58 Estimated errors of calculations

I.1 Purchased Electricity, Heat or Steam

The error of the calculation of the emissions and water usage due to the purchase of electricity, heat or steam is estimated to be lower than 5-10%. The calculation is based on two elements which contain very little unreliability. The conversion factors are given by the official publications provided by the energy companies, verified by an independent research institute (CE Delft) and accepted for publication by the public authority. The required specific input is based on metering equipment that is subject to strict regulations and monitoring and therefore reliable.

I.2 Purchased products, goods, materials

The emissions and water usage due to the purchase of materials and products by the organization are based on averages. The assumptions behind the calculations are numerous; the CBS has based them on average values concerning the entire Dutch economy, the emissions that occur abroad are based on Dutch figures, and the small amount of categories forces grouping of information. Since the deviations within the defined categories are expected to be large, the error is estimated to be lower than 50%.

O.1 Production of Electricity, Heat or Steam
The error of the calculation of the emissions and water usage due to the production of electricity, heat or steam is estimated to be lower than 5%. The calculation is based on two elements which contain very little unreliability. The fuel mix is well known at the organization and therefore the error will be caused by the used conversion factors and will not exceed 5%. The required specific input is based on metering equipment that is subject to strict regulations and monitoring and therefore reliable.

O.2 Transport of materials, products, waste and employees / Le.2 Leased transport
The emissions and water usage due to transportation is expected to be calculated with an error that is smaller than 20%. This is mainly expected due to the difficulty of information collection and not due to the specification of the calculation factors.

The first option to calculate the emissions are based on the average employee profile, the reliability of this approach is highly depending on the ability to estimate an accurate profile. This method can only be applied if the traveling behavior of employees is translatable into such an average profile. The estimation of the error results from the adoption of the used conversion factors and the difficulty of collecting the information. Since it concerns averages of more specific factors, this might introduce errors into the calculations. Information on water usage is not available in this form, and therefore not included in the calculation. If this option is applied due to lack of information to an organization with a homogeneous mobility pattern of its employees it is expected to provide reliable results within a range of error between 10-20%.

The second option includes calculations based on the expenses in a certain category of transport. These figures are based on publication of the Central Bureau of Statistics and therefore assumed to be reliable. The main error in this calculation origins from the deviations from the averages. An example is the figure for use of public transportation. This is based on the average emissions due to the usage of public transportation. Differences between types of public transportation can cause errors into the estimation. Conversion factors of trains, trams and busses are different. The emission factor for the national railway is 0.0602 whilst the factor for a bus is 0.1073 (CBS, 2007). This variety introduces an error into the calculation that is expected to be within 10-20%.

The third option is based on the specific amount and type of fuel that is combusted during the transportation. The estimated error of this option is lower than 5%. The figures are based on calculations from the EPA and the list of standard emission factors. The water usage due to the production of the fuels is based on the study from Hoekstra and Chapagain and also expected to be less than 5%. Due to the fact that the information of the organization is detailed and accurate if stated in this form, than the total error of the calculation does not exceed 5%.

The fourth option is based on the mileage traveled per modality. The extended tab offers the ability to enter highly specific mileage information, and on this level of detail the conversion factors are also available. Altogether the calculations regarding the emissions and water usage due to the transportation activities are estimated to be lower than 10%.

O.5 Consumptive water usage

The calculation of the consumptive water usage from the municipal supply and the emissions due to the production of the freshwater are expected to have errors below 10%. The total amount of water can be directly monitored from the metering equipment that is installed at all water acquiring points of the municipal network. Due to the strict protocols for metering this will not introduce large errors. The calculation of the emissions is based on figures from the water producing companies and the average emissions due to the usage of electricity. Since these figures are accurate, only little error is expected due to differences in installations.

Ou.2 Waste Disposal

The calculation of the carbon emissions due to the disposal of waste is expected to be accurate within a 20% margin. The calculations are based on figures provided by CE Delft, based on personal communication. The emissions factors are based on studies performed by CE Delft. The expected errors occur due to the differences that exist within the six categories. Also the estimates of the production emissions introduce large errors into the calculations. Therefore the expert has judged this element to have 20% error included in the calculations.

Appendix E: Workshop Usability EY

The usability of the instrument was tested by having a representative employee of Ernst & Young Business Advisory Services perform a test case. The goal of the workshop was to test the usability of the instrument based on the stated requirements as were defined in close interaction with the future users (see paragraph 4.3). This appendix describes the workshop as it was performed.

E.1 Participant profile

The participant was selected in close cooperation with the client. Main requirement was to select a person from Ernst & Young Business Advisory Services, Multi National Clients, who was in the rank of 'advisor'. This is the selected rank of people to become the future user as determined by the future user, Ernst & Young. To perform the workshop we selected Marie-Claire Aerts, an advisor at this department with 3 months of working experience. Due to her rank and previous experience she fitted the profile of the participant. It is expected, based on the recruitment procedures in place at this department, that the findings of the test are representative for the other employees at this department.

E.2 Tested requirements

To test the usability of the instrument, the following requirements were tested:

The instrument must be usable by a person with limited expertise of footprint studies.

- B.5. The instrument must be self-explanatory to the user
- B.6. The instrument must be well-documented to support the application
- B.7. The instrument must be easily maintainable to keep general information up-to-date

The instrument must produce well interpretable output

- C.1. The output must support the analysis of the results
- C.3. The output must be interpretable for non-experts

During the workshop the performance of the participant was documented in order to register the performance on these requirements. After the test the participant was asked to grade the performance of the instrument on the different requirements. Together these indicators are used to determine the performance of the instrument on these requirements.

E.3 Case

The case is focused around an imaginary company that is performed a private organization called 'T_Shirt_Com'. This is a medium sized company located in the Netherlands, specialized at the manufacturing of custom t-shirts. The company is situated at one location in the Netherlands.

The company purchases blank t-shirts and modifies them in their production facility. This facility is able to perform different operation on the t-shirts, so they can be modified for their customers. The finished products are transported to the customers by using T_Shirt_Com's trucks. In case there is lack of transport or sales, the products are temporarily stored in a rented storage space. The office is located at the same site and provides working spaces for the other departments of the organization.

The data was provided in the format similar to that in which organization are able to provide the information.

ENERGIEVERBRUIK

Periode 1-1-2008 t/m 31-12-2008
16.958.915 KWH elektra, NUON
243.598 m3 gas
312.865 m3 water

BRANDSTOF LEASEPARK
Kalenderjaar 2008
Ca. 23 auto's
Shell Management Informatiesysteem
Auto: 1.572.336 km

ZAKELIJK VLIEGVERKEER
Periode 1-1-2008 t/m 31-12-2008
BCD Travel Management Informatiesysteem
short haul vluchten business class (tot 500 km): 573.800 km
idem economy class: 124.000 km
long haul business class: 570.000 km
idem economy class: 734.000 km

OPENBAAR VERVOER
Periode 1-1-2008 t/m 31-12-2008
BCD Travel Management Informatiesysteem
NS Business Card: 57.800 km
BRANDSTOF TRUCKS
Periode 1-1-2008 t/m 31-12-2008
1.725.627 liter Diesel

AFVAL
Periode 1-1-2008 t/m 31-12-2008
Van Gansewinkel Client-Info-System
Restafval: 4.523,86 ton
Separate verwerking:
Papier & karton: 3.264,23 ton
Glas: 12,48 ton
Keukenafval: 35,67 ton
Metalen: 0,34 ton

RENTAL STORAGE, ingehuurde storage capaciteit opslag producten
Periode 1-1-2008 t/m 31-12-2008
32.547 kWh Elektra, Essent
= 32.547 * 0,479 = 15.590,01 kgCO2
= 32.547 * 1,8 = 58.584,6 liter Water

RESULTATEN STUDIE GREENCHOICE
Periode 1-1-2008 t/m 31-12-2008
Impact gebruiksfase T-shirts,
89% Wassen
= 65 * 4,7 liter = 305,5 liter Water / T-shirt
= 65 * 0,19 kWh * 0,434 kgCO2/kWh = 5,4 kg CO2 / T-shirt

PRODUCTIE GEGEVENS T-SHIRT DRUKKERIJ
Periode 1-1-2008 t/m 31-12-2008

Productie: 12.398.294 items

CARBON kgCO2/T-shirt		WATER l/T-shirt (Surface)
WASSEN	0,23	14,3
KLEUREN	0,67	2,4
BEDRUKKEN	0,14	0,4

PURCHASED PRODUCTS

Periode 1-1-2008 t/m 31-12-2008

Blanco-T-shirts	€ 2,750,000,-
Papier	€ 25,000,-
Folders / Flyers	€ 175,000,-
Elektrische apparatuur	€ 25,000,-

E.4 Results

The total duration for the workshop was exactly one hour; it took the participant 37 minutes to fill in the data into the instrument, including reading the documentation. After the workshop several questions remained unanswered and had to be discussed. After finishing the test with the instrument the participant filled in a list of questions.

1. ***The purpose of the application of the instrument was:***

- Clear
- ~~Vague~~
- ~~Unclear~~

….for me the purpose of the application of the model is:

to acquire insight into the total amount of carbon emissions and the water usage of an organization.

2. ***The structure of the model was:***

  - Clear
  - ~~Vague~~
  - ~~Unclear~~

….for me, very briefly, the structure of the model can best be described like this:

Inbound: impact of purchasing

Organizations: impact of direct activities performed by the organization

Support: impact of outsourced and leased assets, services, activities

Outbount: impact of the end-product

3. ***Filling in the data into the model was:***

- ~~Easy~~
- Moderate
- ~~Hard~~

Overall it as easy to fill in the data although, sometimes it was difficult to make a distinction between the different options of filling the data into the instrument.

4. The structure of the output was:

- Clear
- ~~Vague~~
- ~~Unclear~~

….for me, very briefly, the structure of the output can best be described like this:

Total output numbers: organizations specific information in numbers

Carbon graphs: output of the carbon emissions represented in graphs

Water graphs: output of the water usage represented in graphs

Output comparison: standardized output to compare outputs to other organizations

5. Interpretation of the output was:

- ~~Easy~~
- Moderate
- ~~Hard~~

Interpreting the output was easy, the information is presented consistent to the structure of the instrument in well interpretable form. Also the units that were used are clear and easy to interpret.

6. Do you have any comments / suggestions regarding the usability of the instrument?

Tab I.2 includes the term 'Product Origin' to describe the different categories in which the organization spent money, or purchased from. This description is unclear and could better be changed into 'Spent category'.

The extended tab in this case is defined in different units, it might be preferable to represent these extended tabs in monetary units as well.

Tab O.1 includes the term 'Heat Production' this can refer to both the heating of buildings and to producing heat for city-heating, industrial processes etcetera. This is confusing and should be adapted into separate categories.

Tab O.2 the distinction between owned vehicles and leased vehicles is not clear, it might be of help to explicitly state this in the title of the tab.

Le.1 in this tab, no pre-defined input is available, therefore the colors that were used to distinguish between the different fields of input, calculation factors and output should be changed. Otherwise the user does not feel like adding data into these pre-defined fields.

Le.2 the difference between the four options and the extended tab should be made more explicit. Otherwise the first-time-user does not know of these different options and the possible level of detail.

Or.2 the different options are not described clear in this case. The distinction between 'tab I.2 has been filled out completely' and 'has not been filled out' is clear, but the first description is unclear to what it applies.

7. What grade would you, based on this experience, give to the different requirements that are stated in this table? Please grade between 1-10, just like 'rapportcijfers'.

The instrument must be able to determine the combined carbon and water footprint of an organization.
8 A.1. The instrument must be generally applicable to any type of organization
8 A.2. The instrument must adopt the developed conceptual model
8 A.3. The instrument must produce valid results

The instrument must be able to identify the main drivers of the organizations' footprint.
8 A.4. The instrument must identify the main drivers causing the size of the footprint
8 A.5. The instrument must determine both the absolute and relative size of the drivers

The instrument must produce output that can be compared to other organizations.
8 A.6. The instrument must calculate the full footprint as defined in the conceptual model
7 A.7. The instrument must produce output in a format that enables comparison of results with peers

Applying the instrument is constrained by a limited budget.
- B.1. The duration of applying the instrument must not exceed 20 working-hours
7 B.2. The instrument must make use of organization specific information that is readily available
8 B.3. The instrument must make use of general applicable information from trusted sources.
- B.4. The instrument must make use of available hard- and software at Ernst&Young

The instrument must be usable by a person with limited expertise of footprint studies.
8 B.5. The instrument must be self-explanatory to the user
9 B.6. The instrument must be well-documented to support the application
9 B.7. The instrument must be easily maintainable to keep general information up-to-date

The instrument must produce well interpretable output
9 C.1. The output must support the analysis of the results
9 C.2. The output must be fit for reporting
7 C.3. The output must be interpretable for non-experts

The instrument must produce outcomes that are fit for reporting

7 C.4. The output of the instrument must have an attractive lay-out

9 C.5. The output of the instrument must include accepted indicators

The overall score that was given to the fulfillment of the requirement by the instrument as was tested in this workshop has an average of 8.05. Most important is to notice the element scoring less than others. The comparison of the output to peers scores (relatively) low and also the interpretability of the output by non-experts. Another important notice is the (relatively) low score for the availability of the information within the organizations.

Appendix F Adopted numbers for calculations

This appendix contains the emission factors as referred to in paragraph **Error! Reference source not found.**. They are published by DEFRA UK and US EPA.

Fuel	CO2 emission factor kg CO2 / gallon	kg CO2 / liter
Gasoline/petrol	8,81	2,327355784
on-road diesel fuel	10,15	2,681346334
residual fuel oil (3s 5 and 6)	11,8	3,117230221
LPG	5,79	1,529556185
CNG	0.054 (kg/ scf)	0.054 (kg/ scf)
LNG	4,46	1,178207355
ethanol	5,56	1,468796613
100% biodiesel	9,46	2,499067618
jet fuel	9,57	2,528126544
aviation gasoline	8,32	2,197911478
E85 ethanol/gasoline		
- biofuel component	4,726	1,248477121
- fossil fuel component	1,3215	0,349103368
B20 biodiesel/diesel		
- biofuel component	1,892	0,499813524
- fossil fuel component	8,12	2,145077067

Figure 59 Combustion factors Fuel Consumption

Vehicle type		Engine size	CO2 emission factor kg CO2/ vehicle km	kg CO2/ vehicle mile
Passenger cars	Petrol	<1.4 l	0,1809	0,29113033
		1.4 - 2.0l	0,2139	0,344238682
		>2.0 l	0,2958	0,476043955
		Don't know/default	0,207	0,333134208
	Diesel car	<1.4 l	0,1513	0,243493747
		1.4 - 2.0l	0,1881	0,302717606
		>2.0 l	0,258	0,415210752
		Don't know/default	0,1979	0,318489178
	Hybrid car	1.4 - 2.0l	0,1262	0,203099213
		>2.0 l	0,224	0,360493056
		Don't know/default	0,2042	0,328628045
	LPG/CNG	1.4 - 2.0l	0,1892	0,304487885
		>2.0 l	0,2594	0,417463834
		Don't know/default	0,2243	0,360975859
Light goods vehicles (e.g. vans)	Petrol	?1.25 tonnes	0,2244	0,361136794
	diesel	?3.5 tonnes	0,2718	0,437419699
	LPG/CNG	?3.5 tonnes	0,2718	0,437419699
	Don't know/default		0,2661	0,428246438
Motorbike		?125	0,0729	0,117321178
		>125 ?500	0,0939	0,151117402
		>500	0,1286	0,206961638
		Don't know/default	0,1059	0,17042953

Figure 60 Combustion factors cars

Vehicle type	Body type	Gross vehicle weight	% weight laden	CO2 emission factor kg / vehicle km	kg / vehicle mile
Heavy goods vehicles	Rigid	>3.5 <7.5t	0	0,525	0,8449056
			50	0,571	0,918935424
			100	0,617	0,992965248
			Don't know/default (40%)	0,563	0,906060672
		7.5 - 17t	0	0,672	1,081479168
			50	0,768	1,235976192
			100	0,864	1,390473216
			Don't know/default (39%)	0,747	1,202179968
		>17t	0	0,778	1,252069632
			50	0,949	1,527267456
			100	1,119	1,800855936
			Don't know/default (56%)	0,969	1,559454336
		Don't know/default		0,895	1,44036288
	Articulated	>3.5 <33t	0	0,672	1,081479168
			50	0,84	1,35184896
			100	1,008	1,622218752
			Don't know/default (43%)	0,817	1,314834048
		>33t	0	0,667	1,073432448
			50	0,889	1,430706816
			100	1,111	1,787981184
			Don't know/default (59%)	0,929	1,495080576
		Don't know/default		0,917	1,475768448
	Don't know/default			0,906	1,458065664

Figure 61 Combustion factors heavy goods vehicle kilometers

Vehicle type				Emission factors (kg CO2 / tonne unit distance)		
				UK Defra emission factors		US EPA emission facto
Type	Subtype	Body type	Gross vehicle weight	kg CO_2 per tonne km	kg CO_2 per tonne mile	kg CO_2 per tonne km
Road vehicles	Heavy goods vehicle	Rigid	>3.5 <7.5t	0,591	0,951122304	0,184547244
		Rigid	7.5 - 17t	0,336	0,540739584	0,184547244
		Rigid	>17t	0,187	0,300947328	0,184547244
		Rigid	Don't know/default	0,276	0,444178944	0,184547244
		Articulated	>3.5 - 33t	0,163	0,262323072	0,184547244
		Articulated	>33t	0,082	0,131966208	0,184547244
		Articulated	Don't know/default	0,086	0,138403584	0,184547244
		Don't know/default		0,132	0,212433408	0,184547244
	Light goods vehicle	Petrol	?1.25 tonnes	0,4488	0,722273587	0,184547244
		Diesel	?3.5 tonnes	0,2718	0,437419699	0,184547244
		LPG or CNG	?3.5 tonnes	0,2718	0,437419699	0,184547244
		Don't know/default	Don't know/default	0,2833	0,455927155	0,184547244
Air	Domestic			2,071	3,332951424	2,071
	Short haul			1,4388	2,315524147	1,4388
	long haul			0,6649	1,070052826	0,6649
Rail				0,021	0,033796224	0,015658554
Watercraft	Large RoPax ferry			0,3843	0,618470899	Not a
	Shipping	Small tanker	844 tonnes deadweight	0,02	0,03218688	0,049709695
		Large tanker	18371 tonnes deadweight	0,005	0,00804672	0,049709695
		Very large tanker	100000 tonnes deadweight	0,004	0,006437376	0,049709695
		Small bulk carrier	1720 tonnes deadweight	0,011	0,017702784	0,049709695
		Large bulk carrier	14201 tonnes deadweight	0,007	0,011265408	0,049709695
		Very large bulk carrier	70000 tonnes deadweight	0,006	0,009656064	0,049709695
		Small container vessel	2500 tonnes deadweight	0,015	0,02414016	0,049709695
		Large container vessel	20000 tonnes deadweight	0,013	0,020921472	0,049709695

Figure 62 Combustion factors heavy goods vehicle tonne kilometers

		UK Defra emission factors	
		Kg CO2/passenger km	kg CO2/passenger mile
Taxis		0,1613	0,259587187
Buses	Local bus	0,1073	0,172682611
	Coach	0,029	0,046670976
	Don't know/default	0,0686	0,110400998
Trains	Light rail	0,09735	0,156669638
	Tram	0,04205	0,067672915
	Average (light rail and tram)	0,078	0,125528832
	national rail	0,0602	0,096882509
	Subways	0,065	0,10460736
Large RoPax ferry		0,1152	0,185396429

Figure 63 Combustion factors Public Transportation

Flight distance	Seating	kg CO2/passenger km	kg CO2/passenger mile
Domestic	NA	0,191077	0,307508623
Short haul	Not known/default	0,107147	0,172436382
	Economy class	0,102133	0,164367131
	First/business class	0,153145	0,246462987
Long haul	Not known/default	0,120554	0,194012857
	Economy class	0,087963	0,141562726
	Economy+ class	0,140719	0,226465278
	Business class	0,25506	0,410479281
	First class	0,351852	0,566250905

Figure 64 Combustion factors aviation