Carbon & Energy Accounting

Greenhouse Gas and Energy Assessment Tool for Dutch non-ETS Companies

Master's thesis

W.B. van Velzen
Utrecht University

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Colophon

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Title: Carbon & Energy Accounting
Greenhouse Gas and Energy Assessment tool for Dutch non-ETS companies

Author: Willem van Velzen
Student nr: 3248941
E-mail: w.b.vanvelzen@students.uu.nl

University Copernicus Institute of Sustainable Development
Utrecht University
Heidelberglaan 2
3584 CS UTRECHT

Supervisors: Dr. Robert Harmsen (first reader)
Prof. Dr. Ernst Worrell (second reader)

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Summary

The Dutch government is determined to comply with the "*Roadmap for moving to a competitive low-carbon economy in 2050"* set by the European Union. If The Netherlands want to reach their greenhouse gas (GHG) emission target, all sectors within the economy have to do their utter best to reduce their carbon footprint. There is a strong focus on heavy industries to comply with the Emission Trading Scheme (ETS). These ETS companies are obliged to report their GHG emissions. For non-ETS companies it is only voluntary to measure their carbon footprint and to take action to reduce it. There is a growing trend for companies to do *something* about their carbon footprint either in the form of reducing or compensating. Within this field many small green consultancy offices jumped in with free online carbon assessment tools. They offer their knowledge to determine a strategy to reduce the carbon footprint and offer carbon offsetting. A close look at these carbon assessment tools reveals several scientific flaws and their methods are not very transparent. As carbon accounting can be seen as a form of (economical) bookkeeping it is important to establish certain ground rules for any carbon accounting tool.

The World Resources Institute and the World Business Council for Sustainable Development developed this carbon accounting standard in the form of the Greenhouse Gas (GHG) protocol. As the GHG Protocol does not provide a carbon assessment tool and does not provide a carbon emission factor database, this is constructed as supplement of this research in the form of a website (www.energiescanner.com). Not only the carbon footprint can be analyzed with Energiescanner but also the energy footprint (MJ) and variable costs (euro) related to energy use. The *standard* carbon and energy factor database is developed specifically for The Netherlands since some factors are country dependent. For example, the electricity mix of a country determines the carbon emission factor of electricity. Some emission factors e.g. how to deal with biomass is still under debate within the scientific community. Also this part of the GHG Protocol is not yet released. Next to the standard database also the database used by SKAO (CO_2-prestatieladder) can be chosen for determining the carbon footprint of an organization. This database is slightly different compared to the *standard* database. The main research question in this thesis is: *To what extent can the developed GHG accounting tool provide consistent insight in the carbon footprint of non-ETS companies and help steering company efforts towards GHG emission reduction?*

The main goal of the website is to offer a scientifically sound platform, which enables non-ETS companies to scan, analyze and reduce their carbon and energy footprint by themselves (without the use of "*consultancy experts*"). The analysis part consists of a feature that allows the user to have insight through easy interpretable interactive charts and standard reports. By simple mouse clicks the user selects the part of the organization (parent or subsidiary), scope/subject and form (CO_2, energy or euro). The main advantage is that users can easily see the main emitting subjects and the variable costs related. This allows the user to make economically feasible decisions towards carbon and energy reduction. This report contains information on how an easy to use greenhouse gas assessment tool needs to be constructed based on the GHG Protocol, the justification of the database behind the tool and how the analysis part is constructed. Also a benchmark with other (free of charge) assessment tools is executed as well as a case study of a fictive organization.

Preface

Initially the plan was to write this report in an internship setting. However after the first few weeks my supervisor (Robert Harmsen) and I decided to perform this thesis without an internship. This gave me more freedom to do my own research according to my own vision.

A large part of this research was the development of a website. The development of a website requires a wide range of skills. As I do not possess all these skills, multiple friends who do have these skills offered me to help. The entire technical part and lay-out of the website is developed and programmed by Jelmer Vernooij. The content of the website is checked by Pieter de Winter. The logo of the website is designed by Minou Kemperman and Niels van Velzen. Some graphics that are used on the website (also used in this report) are developed by Bart Lemcke.

Without the help of these people the website would not exist. The intention is to develop the website to a higher level and start a (part-time) business (Jelmer and myself). The goal of this business is to get as much users as possible for the website and therewith contribute to the development of emission reduction strategies by companies. The work on the subject of this thesis has not yet ended.

The weekly sessions with my supervisor Robert Harmsen to discuss the progress on this thesis increased the efficiency of the process enormously. His profound comments, tips and advice positively steered the process in a great deal. In my entire academic career I have never met a teacher who is willing to invest so much time in students. Also the deviations in the weekly discussions helped me to understand much more of the - for me strange, irrational, full of paradoxes and complex - world of sustainability. Thank you very much for all your time and effort.

I also want to thank the company Loo van Eck who was willing to cooperate by testing the website. Finally I want to thank Bart Gombert who read the report in order to check it on grammar errors.

Willem van Velzen
Utrecht, july 2012

Contents

1. Introduction

In accordance with the "Roadmap for moving to a competitive low-carbon economy in 2050" as set by the European Commission, the goal of the Netherlands is to reduce 80% of the greenhouse gas (GHG) emissions in 2050 (-20% in 2020, -40% in 2030) compared to 1990 (Atsma & Verhagen, 2011). For the period up to 2020 this target consists of two main components that have to contribute to GHG emission reductions. The first component is the Emission Trading Scheme target (ETS), which is covered by the ETS directive and is applied to ETS-sectors (large GHG emitters such as heavy industries). The second component is applied to non-ETS sectors, which is covered by the Effort Sharing Decision (ESD) (Harmsen et al, 2011a). The ESD concern the emissions from sectors not included in the EU Emissions Trading System (ETS) such as transport, buildings, agriculture and waste (European Commission, 2011a).

While sectors in the ETS are regulated at the Community level, it will be the responsibility of Member States to define and implement policies and measures to limit emissions of sectors under the Effort Sharing Decision (European Commission, 2011a). The ESD target for the Netherlands is 16% GHG-emission reduction in 2020 compared to 2005 (PBL, 2011). Within the Netherlands 79% of the workforce is employed within the tertiary sector (mostly non-ETS) (CBS, 2012) and contributes around 73% of the total GDP. The contribution to GHG emissions per unit of GDP is relatively low but due to the size of the sector still significant.

The pressure of the public to tackle climate change and therefore reduce emissions is increasing. Companies find themselves under increasing regulatory and public relations pressure to record, communicate and reduce GHG emissions of goods and services across the value chain (Lash and Wellington, 2007) (Okereke, 2007). Recording GHG emissions is also referred to as carbon accounting.

Insight in GHG emissions means that action can be taken. "*The very act of providing accounts has the potential to change behavior.*" (Buhr, N., 2007, p. 67). An insight in GHG emissions also opens the possibility for benchmarking. The benchmarks are also very important for the achievement of a low-carbon economy. They provide a strong signal for what is possible in terms of low-carbon production (European Commission, 2011b).

1.1 Problem definition

For companies it is important to have a clear framework in order to define a strategy for reducing GHG emissions. As stated by Ascui & Lovell (2011): "*Framing defines the problem (and therefore also its solutions) by structuring the terms of the debate, foregrounding certain forms of knowledge, expertise and practice as relevant and setting limits on what action is judged to be appropriate. Framing is used to make sense of the world, and then actively affects our response.*" The development of an easy to use assessment tool that provides insight in the GHG emissions of a company accompanied by multiple forms of analysis tools can contribute to the Effort Sharing Decision (reducing direct emissions of transport, build environment and small industries) target of the Netherlands. As recital 28 and 29 of the Effort Sharing Decision - *Decision No 406/2009/EC of the European Parliament and of the Council of 23*

April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020 (ESD, 2009) - states:

> *(28) Since the reduction commitment of the Community imposes tasks not only on the central governments of Member States but also on their local and regional governments and on other local and regional advocacy forums and organizations, Member States should ensure cooperation between their central authorities and local authorities at different levels.*
>
> *(29) In addition to individual Member States, central governments and local and regional organizations and authorities, market actors — together with households and individual consumers — should be involved in contributing to the implementation of the Community's reduction commitment, irrespective of the level of greenhouse gas emissions which can be attributed to them*

At the moment there are multiple online carbon assessment tools that claim to be able to calculate the carbon footprint (sum of direct and indirect emissions) of a company. However, these assessment tools often lack transparency. A quick glance at some of those websites reveals several inconsistencies, incompleteness and limitations in providing a deeper insight in the carbon footprint. One2Green (online carbon accounting tool based on the GHG Protocol) for example uses a CO_2 emission factor for electricity of 387 gram CO_2/kWh (compared to 560 gram CO_2/kWh calculated in this report) and does not follow the guidelines of the protocol at all (e.g. separate direct emissions from indirect emissions in the results section) (One2Green, 2012).

According to the website of the Greenhouse Gas Protocol (GHG Protocol) the GHG Protocol is the most widely used international accounting tool for government and business leaders. The website however does not provide an accounting tool, but merely guidelines of the protocol on how to develop your own accounting tool. This subject will be further elaborated in the evaluation of the GHG Protocol (Chapter 8). The International Organization for Standardization (ISO) adopted the Corporate Standard as the basis for its ISO 14064-I in 2006; " *Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals. This milestone highlighted the role of the GHG Protocol's Corporate Standard as the international standard for corporate and organizational GHG accounting and reporting."* (GHG Protocol, 2012). The problem of the ISO certificate is that it costs a lot of money and is a bureaucratic burden. There is also not an accounting tool available for direct use. For most small/medium sized businesses this is therefore not an option.

In conclusion, there is a widely accepted framework available for carbon accounting in the form of the GHG Protocol. However, this framework is not translated into an easy to use accounting tool. The GHG Protocol merely provide guidelines on how to construct a GHG assessment tool, but does not provide e.g. an emission factor database. The problem of guidelines is that they can be interpreted in multiple ways, which may result in inconsistent outcomes. Also the GHG Protocol limits its guidelines to GHG accounting whereas energy accounting is also very important. Energy use and GHG emissions are closely related, analyzing results of the assessment tool from multiple perspectives may result in developing a different, more effective strategy.

1.2 Research question

1.2.1 Central research question

The objective of this research is to develop an easy to use and transparent assessment tool which enables non-ETS companies to get reliable and consistent insight in their Greenhouse Gas emissions (based on the GHG Protocol) and energy use. The central research question related to this objective is: *To what extent can the developed assessment tool provide reliable and consistent insight in the carbon and energy footprint of non-ETS companies?*

1.2.2 Sub-questions

1. What are currently relevant Dutch carbon indicators and thereby carbon intensities based on reliable and consistent calculation methods for direct and indirect emissions for non-ETS companies?
2. What are currently relevant Dutch energy indicators and thereby energy intensities based on reliable and consistent calculation methods for direct and indirect energy use for non-ETS companies?
3. What type of analysis tools are needed within the assessment tool that can contribute to more insight in the carbon and energy footprint?
4. How do the results of the developed assessment tool compare to available web-based GHG assessment tools?
5. To what extent can the developed assessment tool help to develop a strategy in other to reduce GHG emissions and energy use?
6. To what extent are the GHG Protocol and the website of the GHG Protocol shown useful in developing an accounting tool?

1.3 System boundaries

The term *carbon accounting* can be interpreted in multiple ways. The figure below shows different terms of specific interpretations of carbon accounting that can be defined (Milne and Grubnic, 2011). Every intepretation has its own perspective of the accounting method en is therefore essential to define.

Table 1: Carbon accounting definitions

			emissions to the atmosphere		global				
			removals from the atmosphere		national			research	
			emission rights		sub-national			compliance	
estimation			emission obligation		regional			reporting	
calculation			emission reductions		civic			disclosure	
measurement		carbon			organisational	level	mandatory	benchmarking	
monitoring	of	carbon dioxide	legal or financial instruments	at	corporate	for	voluntary	auditing	purposes
reporting		Greenhouse	linked to the above		project			information	
validation		gas	trades/transactions of any of		installation			marketing	
verification			the above		event			or other	
auditing					product				
			impacts of climate change		supply chain				
			impacts from climate change						

Source: (Milne and Grubnic, 2011)

This research will focus on the audit of greenhouse gas emissions to the atmosphere (and energy use) at organisational level for voluntary information purposes (marked red in *Table 1*). Given that at this moment non-ETS companies are not obliged to reduce their carbon emissions within the boundaries of the determined scopes.

The users of the GHG Protocol can be divided into two broad categories:

1. Corporate users: Businesses using the GHG Protocol directly for their own purposes or as participants of voluntary climate initiatives.
2. Non-Corporate users: Governments, NGOs, and others with initiatives or programs based on or informed by the GHG Protocol Initiative.

As already mentioned the study will focus on non-ETS companies (corporate users). This will contribute to homogeneity of the product that can be used for benchmarking purposes between non-ETS companies. The data provided by the assessment tool can be used for more than just information purposes, but this is up to the reporting company. The reporting company can incorporate the information within a report that can be used in a benchmark with other companies in the same sector or it can be used as marketing tool. The energy accounting part follows the same system boundaries as carbon accounting. The audit is entirely voluntary and at this moment just for information purposes. The accounting tool can also be used by non-corporate users.

Boundaries of the assessment tool

The goal is that non-experts should be able to use the assessment tool. The assessment tool should be in balance between easy to use (non-expert) and completeness. The boundaries of the assessment tool will be the same as the boundaries set by GHG Protocol. At this moment everybody can develop a GHG assessment tool and put it on a website. The purpose of developing this assessment tool from a client perspective is providing reliable and consistent insight in carbon emissions and energy use for the client. The client can take action at a voluntary base. The client will not be rewarded in the form of a certificate or whatsoever, but will be able to reduce energy costs. From a scientific perspective the development of an assessment tool is valuable to see whether different methods and input values may lead to different results. Note: The carbon and energy accounting tool will further be referred to as assessment tool or accounting tool in this report.

1.4 Reading guide

The structure of the report is as follow (the green headers are the chapters that contain the results of this thesis):

2) GHG Protocol
- Introduction
- Framework
- Guiding principles
- CO_2 Prestatie-ladder

3) Method
- Operationali-zation protocol
- Accounting
- Benchmark
- Analysis

4) Development Energiescanner
- Framework
- User perspective
- Development database
- Database values

5) Benchmark
- Benchmark Energiescanner against other assessment tools

6) Virtucon
- Case study 1; detailed assessment of a fictive company

First the GHG Protocol will be discussed from all its facets (chapter 2). Secondly the method on how the GHG Protocol will be used in the development of the assessment tool and how the tool is benchmarked and field tested will be elaborated (chapter 3). The following chapter is about the development of the assessment tool Energiescanner, including screenshots of the website (chapter 4). The next chapter contains the results of the developed assessment tool benchmarked against currently available accounting tools (chapter 5); followed by the results of the case study of the fictive company Virtucon (chapter 6).

7) Loo van Eck
- Case study 2; Review of the developed assessment tool by Loo van Eck

8) Evaluation GHG Protocol
- Website and protocol evaluation
- Recommendations regarding GHG Protocol

9) Discussion
- Database values
- GHG Protocol

10) Conclusion
- Main conclusions of this research

The results of the second case study with a real company are not published in this report due to privacy issues. However, Loo van Eck did write a review of the developed website (chapter 7). Also the GHG Protocol itself will be evaluated (chapter 8). The final chapters contain the discussion (chapter 9) and conclusion (chapter 10) of this thesis.

Please do not forget to visit the website of Energiescanner: www.energiescanner.com (Dutch).

2. GHG Protocol

In this chapter the GHG Protocol will be introduced (2.1) followed by the framework of the GHG Protocol (2.2). Also the guiding principles as set by the GHG Protocol for the development of an accounting tool will be discussed (2.3). The last section of this chapter is a small introduction of the CO_2 prestatieladder. The CO_2 prestatieladder is a Dutch instrument which is based on the GHG Protocol (including emission factor database) and thereby closely related to this research (2.4).

2.1 Introduction GHG Protocol

The World Business Council for Sustainable Development (WBCSD) is a coalition of 200 international companies which jointly convened the GHG Protocol with the World Resources Institute (WRI) in 1998. The WRI is an environmental think tank which has a network of 150 members of advisors, collaborators, partners, and cooperating institutions in more than 50 countries. The work of the GHG Protocol is funded by multiple private organizations and governmental institutions.

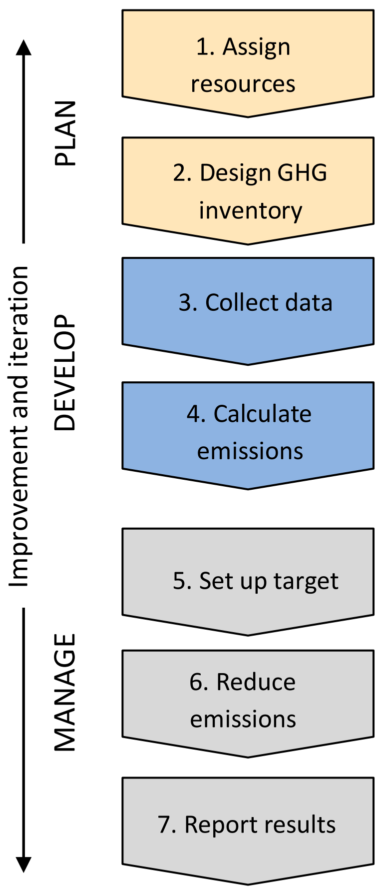
The website of the GHG Protocol describes the GHG Protocol as follows ('About' tab): *"The Greenhouse Gas Protocol (GHG Protocol) is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions.* And: *The GHG Protocol also offers developing countries an internationally accepted management tool to help their businesses to compete in the global marketplace and their governments to make informed decisions about climate change.*" (GHG Protocol, 2011). This phrase is not entirely correct as the GHG Protocol is not an *accounting tool* but a protocol with guidelines on how to develop an accounting tool. There are no complete accounting tools available on the website of the GHG Protocol. This discussion will further be elaborated in the evaluation of the GHG Protocol (chapter 8). The evaluation will be based on experience acquired during this research.

The website of the GHG Protocol is regularly updated with new reports that contain guidelines for specific sectors. The latest release (June, 2012) is: "*Project Launches to Measure and Manage GHG Emissions for Agriculture in Brazil*" (17 June 2012) (GHG Protocol, 2012). Also dates for events and trainings related to the GHG Protocol can be found on the website.

2.2 GHG Protocol framework

This subchapter is partly subtracted of the WRI report: *HOT CLIMATE, COOL COMMERCE: A Service Sector Guide to Greenhouse Gas Management* (Putt del Pino et al, 2006), which can be downloaded free of charge from the website of the GHG Protocol. To understand the reasoning of this research it is needed to have a clear picture of this framework. Therefore the GHG Protocol framework for the development of a GHG inventory is summarized.

The WRI really tries to persuade companies to start with carbon accounting: *"Even if your company recognizes that service-sector companies contribute to climate change, it still must establish a business case to take action. Perhaps the best message to send to your company's decision makers is that GHG management—that is, measuring your company's GHG emissions, setting a reduction target, and implementing your reduction strategy—can build corporate value and earn benefits for your company."* (Putt del Pino et al, 2006, p. 11)



Plan phase

Before starting a GHG inventory it is important that the management board supports the plan. Also the board should *Assign resources (1)* for the established of a team and the development of protocols for e.g. the data gathering process. The next step is to *Design a GHG inventory (2),* this includes setting organizational boundaries and determine sources of emissions.

Development phase

In order to *Collect data (3)* an efficient data management system must be designed. Also a base year must be selected as reference to measure progress over time. Also within this step appropriate data must be obtained with a minimum data quality level. When all data is collected it is time to *Calculate emissions (4).* Important is to guard for calculation errors.

Manage phase

To manage your GHG emissions it is important to *Set a target (5)*. This target must be per definition lower than current emissions, so emission reduction opportunities can be identified. The target can be in absolute terms or in the form of an intensity target. The next step is to *Reduce emissions (6)* by implementing the emission reduction activities. The last step is to *Report the results (7)* so interested stakeholders can be informed on all GHG related activities.

Figure 1: Overview GHG Protocol framework

Source: (Putt del Pino et al, 2006, p. 15)

1. Assign resources (plan)

The GHG Protocol prescribes the following initiatives a company has to take for successful GHG emission reductions. First of all it is important to develop a long term strategy and planning. Also administrative and operational procedures need to be adapted. This means that a budget and team is needed to implement these measures. Participation of as many colleagues as possible might help to track the use of energy or reduce energy by implementing energy conservation measures (behavioral change). It is critical that all these initiatives must be supported by the senior management in order to have success.

2. Design a GHG inventory (plan)

In order to design a GHG inventory the first step is to define the organizational boundaries of the company. There are multiple authorized methods to determine the organization boundary. The equity share method allocates the GHG emissions of subsidiaries as the percentage of shares the parent company owns. The operational control method allocates GHG emissions based on whether or not the parent company has the ability to introduce and implement operating policies at a specific operation (100% allocation if yes, 0% allocation if not). The financial control method allocates GHG emissions on whether or not there is financial control over an operation. If the parent company has influence on the financial and operating policies in order to gain economic benefits from its activities 100% of the GHG emissions must be allocated, if not 0%.

Next is to define the operational boundaries. There is a distinction between direct and indirect emissions. Direct emissions are emissions that are directly controlled or owned by the organization. For service sector companies it applies mostly to boilers and company cars. These direct emissions are subjected to scope 1. Indirect emissions result from activities within the organization but from sources owned or controlled by another company. The most prominent example as source for indirect emissions is electricity use. Every organization uses electricity and most likely this is purchased from an external supplier. The GHG Protocol makes a distinction within indirect emission. As electricity use often makes up a significant percentage of the total emissions it is obligatory to report it under scope 2. All other indirect emission should be reported in scope 3 but are not mandatory.

Table 2 - Overview Scopes

Emissions type	Scope	Definition	Examples
Direct emissions	Scope 1	Emissions from operations that are owned or controlled by the reporting company	Emissions from combustion in owned or controlled CHP's, boilers, furnaces, vehicles, etc.;
Indirect emissions	Scope 2	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company	Use of purchased electricity, steam, heating, or cooling
	Scope 3	All indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions	Employee commuting in vehicles not owned or controlled by the reporting company. Production of purchased products, transportation of purchased products, or use of sold products

Source: (Bhatia et al, 2011, p. 28)

Figure 2 provides a schematic overview of all relevant subjects per scope. For a complete list of the defined subjects that cause emissions, see Annex A.

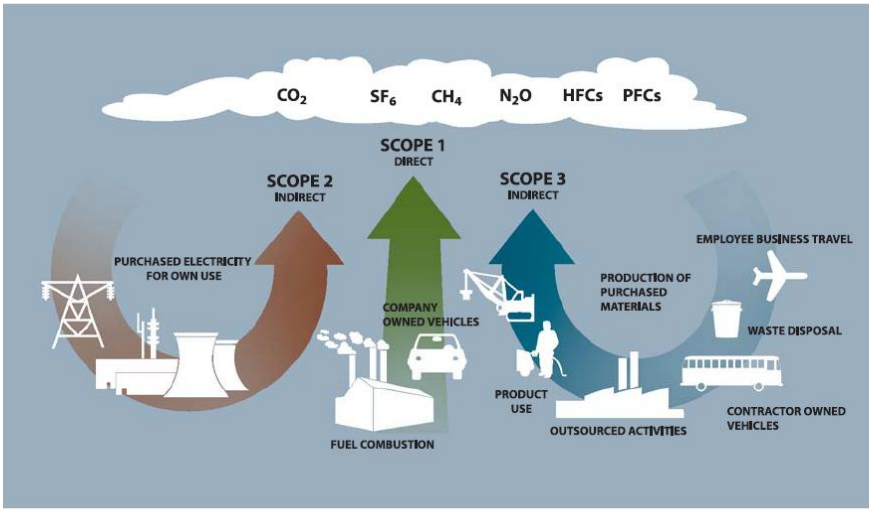


Figure 2: Overview subjects per scope
Source: (Putt del Pino et al, 2006, p. 23)

3. Collect data (develop)
The most important and difficult part is to collect all relevant data. The website of the GHG Protocol provides calculation tools that can assist (tips and tricks) for the collection of data, but as already mentioned these are difficult to understand. First activity data must be collected of all subjects within the scopes, e.g. liters of fuel used by the company car fleet or total electricity use in kWh. To convert the activity data into GHG emissions it is needed to have reliable emission values such as grams CO_2 per Liter [g CO_2/L] of fuel.

4. Calculate emissions (develop)
There are multiple ways to calculate GHG emissions. If data regarding fuel use of company cars is unavailable it is also possible to calculate GHG emissions by combining distance traveled (kilometers) and emission factors expressed in vehicle kilometers (taken into account the size and efficiency of the car). The GHG Protocol mentions a hierarchy in preferred methods for calculating GHG emissions per subject. The higher the accuracy in activity data the higher the quality of the GHG inventory (liters of fuel preferred above distance traveled).

5. Set up target (manage)
To measure the performance of reducing GHG emissions over time it is useful to have a base year as reference. This can be complicated, because you need reliable historical data of the selected base year. When structural changes occur due to acquisition or mergers it is relevant to recalculate the emissions of the base year to reflect structural changes. Also recalculation of historical emission years should be done when significant errors are found in the activity data or used emission factors. The target itself could be in absolute targets (e.g. 25% reduction in 2020) or intensity targets (e.g. 20% reduction per euro turnover). Both absolute targets as intensity targets have advantages and disadvantages.

6. Reduce emissions (manage)

There are multiple ways to reduce GHG emissions for service-sector companies. It is likely that most emissions occur due to heating the building, electricity use and transportation (business travel, commuting). Reducing these emissions can be accomplished by switching from electricity supplier (grey to green) and by e.g. increasing the efficiency of the car park. It is also possible to offset GHG emissions to reach your goal.

7. Report the results (manage)

The following information is required reporting under the framework of the GHG Protocol (Putt del Pino et al, 2006, p. 59, 60):

- Emissions in metric tons and in tons of CO2-equivalent.
- Total scope 1 and scope 2 emissions.
- Separate emissions from each scope plus the total emissions from each scope, showing the sum of your company's emissions.
- The chosen base year and your company's emissions performance over time compared with that of your base year and reduction target.
- Methodologies used to calculate emissions, including emission factors and their sources, or a reference or link to the calculation tools used, with the same information.
- Appropriate context for any significant emission changes such as acquisitions or divestitures, outsourcing or insourcing, changes in reporting boundaries, and base-year recalculations.
- If applicable, leased electricity that must be reported in scope 3.

The following information is optional reporting:

- All other scope 3 emissions. A description of any emission reduction activities.
- A description of offset projects invested in and information about the offsets' credibility, as well as how much of the reduction target was achieved using offsets.
- A description of inventory-related activities planned for the coming year.

Development accounting tool based on GHG Protocol framework

The objective of this research is to develop an assessment tool based on the described GHG Protocol framework. The goal is that the developed assessment tool lowers the entry barrier for organizations to start with accounting of their carbon emissions and energy use. Chapter 4 of this report is reserved to the development of the accounting tool and how the GHG framework (seven steps) is implemented.

2.3 Guiding Principles to develop a carbon accounting inventory

The GHG Protocol defines five guiding principles which must be incorporated within a carbon accounting inventory. The report '*Designing a Customized Greenhouse Gas Calculation Tool'* published by the WRI states: "*Principles are the general guidance for the "spirit" to be followed in developing an inventory when the exact "letter" is unclear*." (Daviet, F., 2006, p. 15). These guiding principles are essential in this research as the guide the process of the objective to develop an assessment tool that provides consistent insight in carbon emissions and energy use. The definition used in the objective covers the five guiding principles defined by the GHG Protocol.

Figure 3: Guiding principles of the GHG Protocol
Source: Figure own design

Relevance: *"Define boundaries that reflect the GHG emissions of your business and the decision-making needs of the inventory users."* (Putt del Pino et al, 2006, p. 19)

Completeness: "*Account for all emissions sources and activities within your chosen organizational and operational boundaries. Justify specific exclusions.*" (Putt del Pino et al, 2006, p. 19)

Consistency: "*Allow a comparison of emissions performance over time. State any changes in the basis of reporting to make sure the comparison remains valid.*" (Putt del Pino et al, 2006, p. 19)

Transparency: "*Address all relevant issues, based on a clearly marked audit trail. Disclose any important assumptions, and cite the calculation methodologies used.*" (Putt del Pino et al, 2006, p. 19)

Accuracy: "*Ensure that your GHG calculations are accurate, and provide reasonable assurance of the GHG information's integrity.*" (Putt del Pino et al, 2006, p. 19)

2.4 SKAO: CO_2 prestatieladder

Within the Netherlands Prorail took the first initiative to develop an instrument based on the GHG Protocol which measures the CO_2 performance of their suppliers (SKAO, 2012). The instrument represents the inventory of GHG emissions of an organization linked to a certification scheme. Initially this instrument was only in use by ProRail, but soon it became apparent that other contractors (of other sectors) saw the potential of the instrument. Suppliers which act on their performance regarding CO_2 emissions receive a competitive advantage in the form of a discount on the assessment of the tender; the tender amount is lowered by a percentage (determined by the client) and thereby more attractive (e.g. tender amount is Euro 100.000, due to a level 4 rating the client assess the amount as Euro 95.000). This instrument is called the *CO_2 prestatieladder* and is now available for all contactors (not limited to Prorail) who are interested in working with suppliers who are aware of their emissions. The ownership of the instrument is since 16 march 2011 held by *Stichting Klimaat-vriendelijk Aanbesteden & Ondernemen* (SKAO). SKAO does not use an online calculation tool but has its own emission factor database, which can be used to calculate the total emissions of a company. Only a certified auditor (registered by SKAO) is authorized to asses an organization that wants to be certified. SKAO does not follow the GHG Protocol completely but made some adjustments of their own. For more information it is possible to download the manual free of charge from their website: "*handbook CO_2 prestatieladder*".

Main differences CO_2 Prestatieladder versus GHG Protocol

As shown in Figure 4 the CO_2 prestatieladder counts '*business travel*' and '*personal cars for business travel*' in scope 2, while according to the GHG Protocol it should be counted in scope 3. A second large difference is that the CO_2 prestatieladder calculates emissions with wrong emission factors; they include indirect emissions for the extraction, production and transportation of fuels in scope 1, while it should be reported in scope 3 (further explained in chapter 3.2). Also the emission factor of electricity (important source of emissions in service sector companies) is likely to be too low (455 gram CO_2 per kWh).

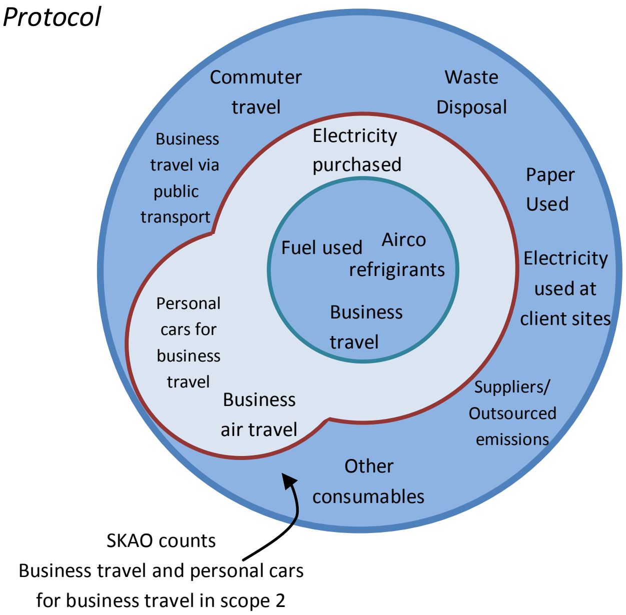


Figure 4: CO2 prestatieladder (partly translated from Dutch)
Source: (SKAO, 2011, p. 51)

3. Method

This research can be seen as an operationalization and extension of the GHG Protocol framework (3.1). An important aspect of the research is the accounting method (3.2). Also the developed tool will be benchmarked against already available tools (3.3). Finally the developed accounting tool will be tested in the form of a case study (3.4).

3.1 Operationalization GHG Protocol

The main part of this research is the construction of a carbon and energy assessment tool. According to Bown and Wittneben (2011) Carbon accounting systems has to evolve on three levels:

1. Scientific knowledge of how to recognize and count GHG emissions;
2. Accounting effort to collect and record this information;
3. Accountability systems to compare this data.

Chapter 4 of this research will be used to elaborate the objective of this research: the development of an easy to use and transparent assessment tool which enables non-ETS companies to get reliable and consistent insight in their Greenhouse Gas emissions (based on the GHG Protocol) and energy use.

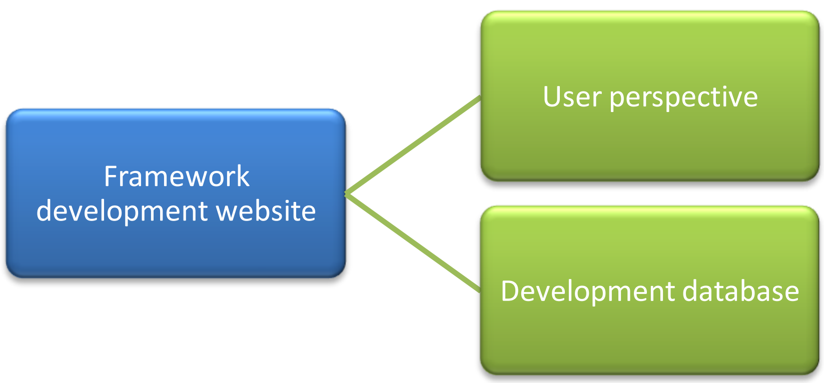


Figure 5: Development of an easy to use and transparent assessment tool
Source: Figure own design

First a framework will be developed to build a web-based accounting tool linked to the framework of the GHG Protocol (2.2) and the guiding principles (2.3). The next step is to translate the framework into an easy to use assessment tool from a user perspective. A large part of this research is dedicated to the development of a database with values that are needed to calculate the carbon and energy footprint. This database is for a large part responsible to get reliable and consistent insight in the carbon and energy footprint.

3.2 Carbon and Energy accounting and financial insight

Calculating Carbon emissions and Energy use
In order to calculate GHG emissions multiple factors should be recognized. The most general equation to calculate GHG emissions is:

Equation 1: General equation GHG emissions

*activity data (a) * emission factor (b) = GHG emissions*

a) Activity data: "*Activity data quantify an activity, such as employee business trips, in units that will help you calculate the emissions generated*" (Putt del Pino et al, 2006, p. 33). The user of the calculation tool is responsible for collecting the activity data, but will be supported by the tool. In most events there are multiple methods to calculate the activity data. The accuracy of these methods differs; the tool provides a ranking in guiding methods to calculate the activity data. The most accurate method will be used first, if data this is not sufficient other (less accurate) methods will be provided. E.g. most accurate entry: usage of gasoline per year [$liter_{gasoline}$/year]; less accurate entry: kilometers driven by car per year [km/year].

b) Emission factor: "*Emission factors convert activity data to emission values*" (Putt del Pino et al, 2006, p. 33). The emission factors are embedded within the calculation tool. All emission factors are based on the Dutch situation. As energy must be extracted, converted into useful energy, transported, stored and distributed losses occur within the energy supply side. The GHG Protocol makes a distinction between direct and indirect emissions. This means that different emission factors must be used within the different scopes. Example of emission factor [gram CO_2/Liter]. GHG emissions are presented in [Ton CO_2/year]. In most reports like the IPCC report carbon emission factors of fuels are provided in kg/GJ. As most activity data will be provided in liters it is useful to recalculate the emission factors of fuels by the energy density of the fossil fuel resulting in g/L: Emission factor [g/MJ)] * Energy density [MJ/L] = Emission factor per Liter [g/L].

Important to notice is that the GHG Protocol only provides guidance on collecting activity data and selecting appropriate emission factors. In order to calculate energy use the same method is applicable as for carbon accounting. The most general equation to calculate energy use is:

Equation 2: General equation energy use

*activity data (a) * energy factor (b) = Energy use*

The same activity data can be used for energy accounting as for carbon accounting. The energy factor however is calculated in [MJ/L]. All calculations are made per year so this equation results in energy use in [MJ/year].

Financial insight

During the inventory it is a small step to also account for the variable costs regarding the activity data. Detailed information about the carbon emissions, energy use and variable costs involved opens opportunities in the form of financial analysis. As for carbon and energy accounting the method behind the general equation has similarities:

Equation 3: General equation energy use

*activity data (a) * money factor (b) = Money spent*

Again the activity data is similar as for carbon and energy accounting. The money factor is calculated in [Euro/L]. This finally results in money spent in [Euro/year].

Exemptions in determining emission factors

Not all emission and energy factors are constants. For example the emission and energy factor of electricity [gram CO_2/kWh], [MJ/kWh] is not equal every year. This is due to changes in the power mix of the Netherlands (e.g. different shares of use of fossil fuels, more installed capacity of renewables). A different emission factor with unchanged activity changes the total GHG emissions and energy use (see Equation 1). Also the emission factor itself is not a fixed number but can differ based on the used database; there is not always consensus in literature (Harmsen and Graus, 2012). The GHG Protocol states in this case that the guiding principles should be used leading in the determination of the values. This research will result in two emission factor databases. The first database will be based on own literature research and the second database will be on factors provided by SKAO.

3.3 Benchmark against currently available GHG assessment tools

At the moment there are already multiple online GHG assessment tools. This chapter defines a method to investigate to what extend the developed GHG assessment tool relates to currently available GHG assessment tools. The calculation tools mentioned in Table 3 will be used as benchmark against the developed tool (Energiescanner). Due to the focus on Dutch companies in this study and the fact that some emission factors are country specific (e.g. electricity) the calculation tool must be developed for the Dutch market.

Table 3: Used calculation tools to benchmark against Energiescanner

	Name calculation tool	Website
1	One2green	http://www.one2green.com/sustainable/carbon-footprint
2	Fairclimatefund	http://www.fairclimatefund.nl/klimaatneutraal-voor-organisaties/klimaatscan/
3	Climate Neutral Group	http://climateneutralgroup.com/diensten-klimaatneutraal/co2-calculator-compensatie/organisaties/
4	Zeeuwsklimaatfonds	http://www.zeeuwsklimaatfonds.nl/co2-calculator

In February 2012 TNO published a study regarding the comparison of online carbon calculation tools focused on transport activities (TNO, 2012). The method used in this research to benchmark currently available GHG calculation tools is partly derived from the research of TNO, supplemented with the five guiding principles of the GHG Protocol (chapter 2.3).

As shown in Table 4 the method consists of five major comparison criteria with subcriteria. There are multiple methods (1) available for the calculation of GHG emissions. Therefore it is important that the tool is transparent on which method is used. Not every calculation tool provides enough options to enter the activity data (2. Input) or lacks subjects that cause emissions in the reporting company. The calculation (3) part is from a technical point of view not very difficult but major flaws can be made when the emission factor database is not accurate. A good calculation tool is transparent on the used database. The presentation of the results (4) is important for the reporting company as they want insight in their emissions and not just the opportunity to offset their emissions by using their credit card. At last the usability of the tool (5) will be benchmarked in the form of the availability of an instruction manual, costs involvement, accessibility, download opportunities and language.

Table 4: Carbon calculation tool benchmark framework

Data	Content	Principle GHG
Name	Name of the paper/calculator	
Country	Country of origin	
	1. Method	
Method/Protocol	What is the used calculation method?	*Transparancy*
	2. Input	
Reliability activity data options	Input asked on fuels and distance traveled, number of available fuels	*Relevance, accuracy*
Completeness	Availability subjects (related to subjects in scopes GHG Protocol)	*Completeness*
	3. Calculation	
Transparency emission factors	Emission factors are directly visible within the tool	*Transparancy*
Source	Internal source (own resource/model) or external source (including reference)	*Transparancy, accuracy, consistency*
Verifiable	Whether the exact source (including the exact data) of the emission factor can be retrieved	*Transparancy*
	4. Results	
Absolute numbers	Distribution of results (aggregation, per subject)	*Consistency*
Relative numbers	Results shown per relative unit (e.g. turnover)	*Relevance*
Graphs	Results presented using graphs	*Completeness*
Monitoring	Attention to monitoring and reduction goals	*Completeness*
Other	Other available tools?	*Completeness*

5. Usability tool		
Manual	Available instruction manual?	*Completeness*
Cost	Costs involvement	
Access	How to gain access (login, etc.)	
Reporting	Download opportunities	*Completeness*
Language	Available languages for the tool	

3.4 Sensitivity analysis, results and strategy forming

The main goal of the developed assessment tool is that insight in carbon emissions and energy use lead to action in the form of implementing a reduction strategy. The three-step approach of the website is 1. Scan (inventory), 2. Analyze (use analysis tool) and 3. Reduce (further elaborated in chapter 4.2).

To measure whether the developed assessment tool is fulfilling this goal, two case studies will be performed. The first case study is the assessment of a fictive company called Virtucon which has multiple opportunities to lower their carbon emissions, but they do not have insight which opportunity is the most effective. The activity data of Virtucon will be used as input for the developed assessment tool as for assessment tools that are already on the market (same tools as used for benchmark, Table 3). By benchmarking the results of the assessment it is possible to analyze whether or not the developed assessment tool has an added value compared to the already available (free) assessment tools. Due to privacy issues fictive activity data will be used in the case study. The second case study is of a real company. The company Loo van Eck is willing to use the developed assessment tool and provide feedback in the form a written review (the results of the assessment are not published due to privacy issues).

Case study 1) Fictive company Virtucon

Virtucon is a company that is specialized in product design. There core activities are making online 3D models and play an advisory role for their customers. The office is located in Utrecht and has a surface area of 600 m^2. The electricity (grey) use is 45,000 kWh and gas use 8,500 m^3 per year. In total 15 employees use lease cars (financial lease) in which they travel in total 300,000 kilometers per year (of which approximately 75% is commuting and 25% business travel). According to the fuel cards they used 12,000 liters of diesel and 6,500 liters of gasoline. Also five employees commute by bike and five employees use the train and bus (in total 57,500 passenger kilometers by train and 2,300 passenger kilometers by bus).

The company owns 2 cars which are used for business travel (total distance traveled: 60,000 km using 4,000 liters of diesel). Also they made 10 business trips by airplane (10 short trips of single 1,500 passenger kilometers, 8 medium trips of single 3,500 passenger kilometers and 2 long trips of single 8,500 passenger kilometers) and 6 trips by international train (average 900 passenger kilometers per trip). The investment opportunities as defined by Virtucon are:

Project A – Replacement of an old air-conditioning unit
In order to replace an old air-conditioning unit with a more energy efficient unit will require a net-investment of EUR 15,000. It is expected that the yearly electricity savings are 5.000 kWh.

Project B – Replacement of 2 company cars
The net-investment costs of the replacement of two company cars will be EUR 60,000. The current cars have an efficiency of 6.7 liters of diesel per 100 km. The replacement cars have an efficiency of 5 liters of diesel per 100 km, saving 1,020 liter of diesel per year.

Project C – Placing solar panels
The installation of solar panels with a power output of 10 kWpeak will have net-investment costs of EUR 25,000. On average the solar panels are expected to deliver 9,000 kWh per year.

CO_2 abatement cost curve
The projects will be compared and analyzed using a CO_2 abatement cost curve. To determine the specific CO_2 mitigation costs the following equation (Blok, K., 2007) is used:

Equation 4: Specific CO_2 mitigation costs

$$C_{spec,\,CO_2} = \frac{\alpha * I + C - B}{\Delta M_{CO_2}}$$

Where,

Equation 5: Determining α

$$\alpha = \frac{r}{1 - (1+r)^{-L}}$$

Legend	
α * I	= annual capital costs (based on net-investment* costs)
C	= annual operation and maintenance costs
B	= annual benefits
ΔM_{CO_2}	= annual amount of avoided amount CO_2 emissions
r	= discount rate
L	= Lifetime of the project

Within this research the discount rate (r) is determined on 5%.

* Net-investments are the investments costs of the project (e.g. more efficient technology) minus the residual value of the technology that is currently in service. Assuming that the technology that is currently in use is sold in thereby fully depreciated.

Net-investment$_{(project)}$ = investment costs$_{(project)}$ - residual value $_{(technology\ currently\ in\ service)}$

Case study 2) Loo van Eck
Loo van Eck is a consultancy office focused on training and advice in the field of communication. They will use Energiescanner to determine their carbon and energy footprint. Due to the privacy-sensitive information that is associated with carbon and energy accounting feedback will only provided in the form of a review of Energiescanner. This review will evaluate all aspects regarding the use of Energiescanner and the results provided by Energiescanner.

4. Development accounting tool: Energiescanner

First the framework on which the accounting tool is based will be described (4.1). The next chapter elaborates on the constructed accounting tool from a user perspective (4.2). In the following chapter the development of a consistent database with carbon and energy factors will be described (4.3), followed by the values of the carbon and energy factors (4.4).

4.1 Framework web-based accounting tool

The objective of this research is to develop an easy to use and transparent (web-based) assessment tool which enables non-ETS companies to get reliable and consistent insight in their GHG emissions and energy use. As described in chapter 2.2 it takes seven steps to create a carbon accounting inventory. During the development of the inventory it is important to keep in mind the five guiding principles (chapter 2.3). The importance of these guiding principles are also recognized in scientific literature such as Bown & Wittneben (2011) who mention three main pillars for carbon accounting are accuracy, consistency and certainty.

Framing the objective

The easy to use part means that not every company has to re-invent the wheel in the form of building an accounting inventory from scratch. Users should not have to become an expert in the field of carbon accounting in order to calculate a carbon footprint. The table below provides an overview who is in control or responsible of a specific step of the GHG Protocol framework.

Table 5: Development of a reliable and consistent accounting tool

GHG Framework	Control/responsible	Guiding principle
Step 1) Assign resources	Reporting company	Relevance
Step 2) Design GHG inventory	Energiescanner	Relevance, Completeness
Step 3) Collect data	Reporting company	Accuracy (activity data)
Step 4) Calculate emissions	Energiescanner	Consistency, Transparency, Accuracy, (database)
Step 5) Set up target	Reporting company	Relevance, Transparency
Step 6) Reduce emissions	Reporting company/ Energiescanner	Relevance, Completeness, Consistency, Transparency
Step 7) Report results	Reporting company/ Energiescanner	Relevance, Completeness, Consistency, Transparency, Accuracy

Step 1) Assign resources

The reporting company has to form a project team who are responsible for setting the boundaries of the company and adapt some of the administrative and operational procedures in order to gather *relevant* activity data. This team will stay responsible for the whole project and need to have the support of the senior-management.

Step 2) Design GHG inventory

Energiescanner is responsible for the design of the GHG inventory. All *relevant* subjects that use energy and/or emits GHG emissions must be incorporated in the tool. As unexpectedly an emission subject is missing for the reporting company there is always an available subject in every scope called: “Other”. The justification of the subject “other” however must be described in the carbon footprint report by the company itself. This way of working secures the *completeness* of the GHG inventory of the reporting company.

Step 3) Collect data

Without *accurate* activity data it is impossible to get reliable insight in the GHG emissions and energy use of the reporting company (garbage in is garbage out.). The qualities of the administrative and operational procedures (step 1) are vital for determining accurate activity data. The reporting company is full responsible for this step.

Step 4) Calculate emissions

The calculation of GHG emissions and energy use relies on two terms (Equation 1) activity data and emission/energy factors. In order to get reliable and consistent insight in GHG emissions and energy use the emission/energy factor database needs to be *consistent*, *transparent* and *accurate*. Energiescanner is full responsible for this part. The development of the database and the values of the database itself are described in chapter 4.3 and 4.4 of this report. To be fully transparent this report can be downloaded free of charge from the website.

Step 5) Set up target

The reporting company is responsible for determining a reduction target. The target however needs to be *relevant* and *transparent* for the employees of the reporting company. Energiescanner is developed in such a way that it is very easy to set up targets and measure the performance over time.

Step 6) Reduce emissions

The reporting company is responsible for implementing measures to reduce GHG emissions and energy use. Energiescanner is responsible for tracking the effectiveness of the implemented measures. The implemented measures must be *relevant* (effective), *completely* inventoried, *consistent* measured over time and *transparent* for stakeholders of the reporting company.

Step 7) Report results

The (yearly) report must fulfill all guiding principles set by the GHG Protocol. The data must be *relevant*, *complete* (no selective reporting), *consistent* (calculating perspective/tracking performance over time), *transparent* (activity data and emission/energy factors) and finally *accurate*. Energiescanner is responsible for generating standard reports. The reporting company is responsible for reaching all criteria set by the GHG Protocol (described in chapter 2.2).

The ‘manage’ part (step 5, 6 and 7) will be further elaborated in chapter 4.2.3.

4.2 Energiescanner design from the user perspective

The target group of Energiescanner is likely to be a non-expert in the field of sustainability and carbon and energy accounting. It is therefore essential that the website is easy to use for this target group (users of the tool/ reporting company). The Plan, Develop and Manage phase of the GHG Protocol is from a user perspective re-designed into:

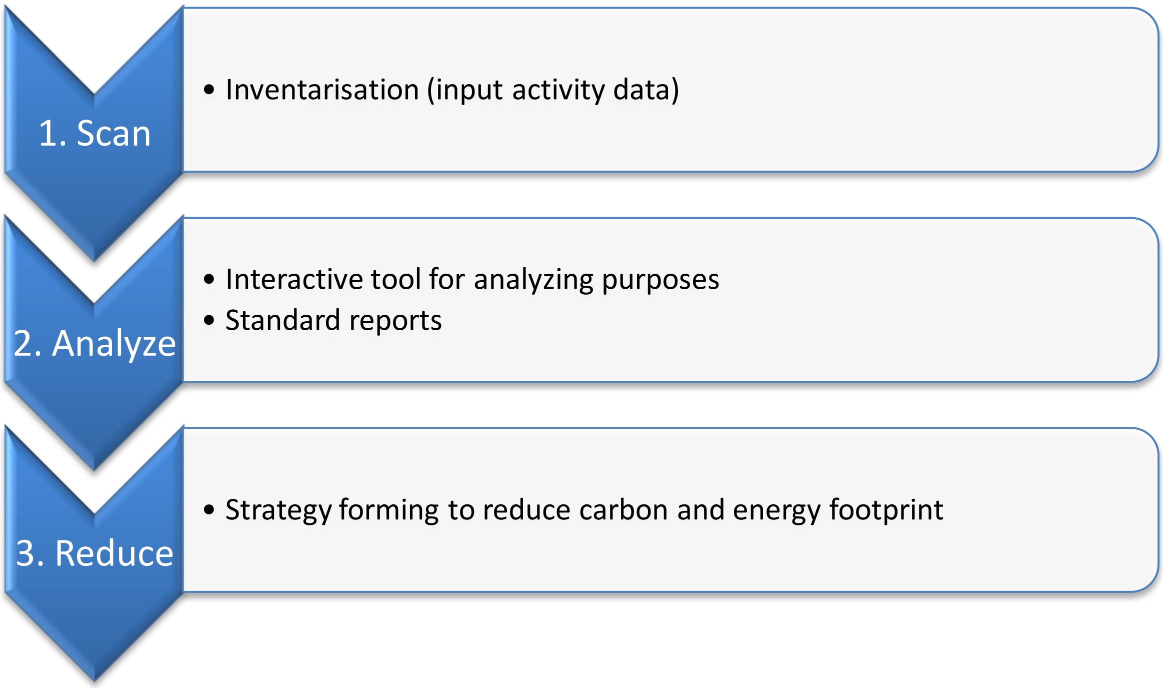


Figure 6: Main steps Energiescanner from a user's perspective

Every step will be further elaborated in chapter 4.2.2 till 4.2.4.

Energiescanner website and technical details

In the upcoming sections within this subchapter the possibilities and functions of the will be described. The technical part of the website is programmed in Python (see Figure 7) whereas the rest of the website is programmed in HTML.

```
# Fuels
motor_gasoline = Fuel("motor_gasoline", "Benzine", unit="L",
    first order co2=2287.00, ere co2=.180, first order energy=33.00, ere energy=0.120, price=1.43)
```

Figure 7: Python code for programming (hard code) database values

Source: Source code Energiescanner

The figure above is a screenshot of how the carbon and energy factors are hard coded in Python. The schema/framework of the code will be further elaborated in chapter 4.3.5.

4.2.1 Interface Energiescanner

The figure below is an actual screenshot of the homepage of the website Energiescanner (july, 2012). It is the first page a user will see when the website is loaded in the web browser.

Figure 8: Screenshot homepage Energiescanner

Source: www.energiescanner.com

1) **Home** – The home page contains concise information what the purpose is of the website and who the target group is.

2) **Background** – A mouse click on '*background*' reveals a drop down list with more elaborated information on the *Target group*, information about what a *Carbon footprint* is, a short introduction to the *GHG Protocol*, some information about the CO_2 *prestatieladder* and the *Roadmap of Energiescanner*. None of this information is essential for a user to perform the scan. It is background information for the more interested client.

3) **Scan** – When the *'Scan'* button is clicked the real scan begins. This step is further elaborated in chapter 4.2.2. The Analysis feature is also in this section (further elaborated in chapter 4.2.3)

4) **Report**: When the *Scan* is complete the user is able to download a standard report. This report contains graphs and tables which provides all relevant information as stated by the GHG Protocol.

5) **Reduction**: Also this button contains a drop down list focusing on reduction. Information can be found on *How to proceed...,* determining a *strategy*, *Chain reduction, Reduction and cost savings* and finally some *facts and discussion* (further elaborated in chapter 4.2.4).

6) **Log in**: The reporting company can log in with e-mail and password. All data entered in previous sessions is automatically restored.

7) **Create account**: If the reporting company has not an account it can create an account here.

4.2.2 Function: Scan

1. Select emission/energy database

As already mentioned the reporting company can choose between two databases. The standard database (developed within this research) or the database which is used by SKAO. The standard database is recommended as it provides a more consistent overview of the carbon footprint.

2. Define organizational boundaries

The next step - before the actual scan is carried out - is to define the organizational boundaries of the organization. The figure below shows different methods that are accepted by the GHG Protocol (see chapter 2.2) for determining the organizational boundaries.

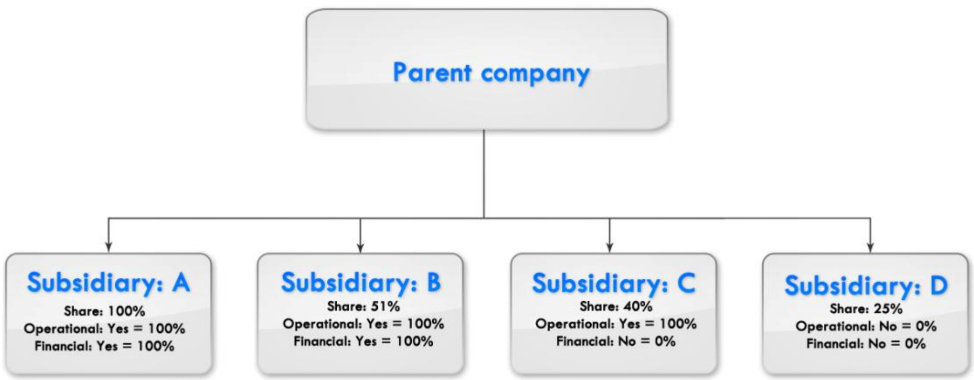


Figure 9: Setting the organizational boundaries of the reporting company

Source: Figure own design

3. Enter activity data

For every part of the organization it is possible to add activity data separately for a specific reporting year. When a new part of the organization is added, automatically reporting years will appear (start year: 2005 – current year, at this moment 2012). With a mouse click on the reporting year of a specific part of the organization, the form, in which the activity data can be filled in, will open in a new window.

Organization

		Share %	Reporting year							
Name parent company:	A	100	2005	2006	2007	2008	2009	2010	2011	2012
Subsidiary 1:	B1	100	2005	2006	2007	2008	2009	2010	2011	2012
Subsidiary 2:	B2	51%	2005	2006	2007	2008	2009	2010	2011	2012
+ Add more										

Figure 10: Overview of a reporting organization (example)

Source: www.energiescanner.com

A green color means that the user already entered activity data in the specific reporting year.

The figure below is an actual screenshot of the form as presented on the website.

Figure 11: Screenshot activity form Energiescanner

Source: www.energiescanner.com

1) Represents the title of the subject. This specific example represents scope 1, subject 1: "*Combustion of fuel in boilers, furnaces, etc. that are owned or controlled by the reporting company*" (translated from Dutch).
2) The fuel type can be selected here. Most boilers work on gas, therefore this type of fuel is selected in this example. The fuel type can be selected from a drop-down list.
3) The activity can be filled out here. In this example 1,000 m^3 is allocated to this specific company part.
4) Sometimes multiple types of fuels are used for a specific subject. To overcome this problem a "new activity" can be created. By clicking on this button a new (empty) line is created to enter activity data.
5) The results of the energy use, carbon emission and costs involved of the activity in the subject are presented here. This example shows that the company used 1,000 m^3 gas which is responsible for 31.7 GJ of energy use, 1.8 ton CO_2 emissions and 420 euro[1] variable costs involved.
6) This button enables the user to delete the activity (e.g. when a mistake is made)
7) Because most of the users are expected to be non-experts, information is provided on how to deal with this specific subject. Also tips and tricks are provided on how to find the most accurate activity data. In this case the most accurate activity data can be found on the balance sheet of the utility company.

All main subjects that cause emissions and use energy in non-ETS companies are listed in the form. As unexpectedly an emission source cannot be allocated to the standard subjects determined by Energiescanner, there is always an available subject in every scope called: "Other". The justification of the subject "other" however must be described in the carbon footprint report by the company itself.

[1] The price per unit of a specific fuel is an average price of the reporting year. It is possible that the reporting company paid another amount. It is possible to change the price per unit and thereby the total costs.

4.2.3 Function: Analyze

The main purpose and strength of the developed GHG assessment tool is that it has a build in analysis tool which can help determining the strategy in order to reduce GHG emissions.

All data regarding the head office and subsidiaries can be filled in separately. The main advantage of allocating the activity data to the responsible part (parent company/subsidiary) of the organization is that the performance of the parts can also be analyzed separately. It is also possible to see sub results on scope or even subject level. For example, the user wants to see the gas use to heat the building in which subsidiary 1 is located; Mouse click on *subsidiary 1* and mouse click *Scope 1, subject 1 – heating*. The results will be presented in the form of a graph over time. Comparing the results with other parts of the company may result in action in the form of analyzing why subsidiary 1 is performing more efficiently comparing to subsidiary 2. Also this feature allows the user to gain quick insight which subjects in which part of the organization contributes the most to the total carbon footprint.

+ Head office
  - Subsidiary 1
  - Subsidiary 2

+ Sources of emissions
  + Scope 1
  + Scope 2
  + Scope 3
    - Subjects

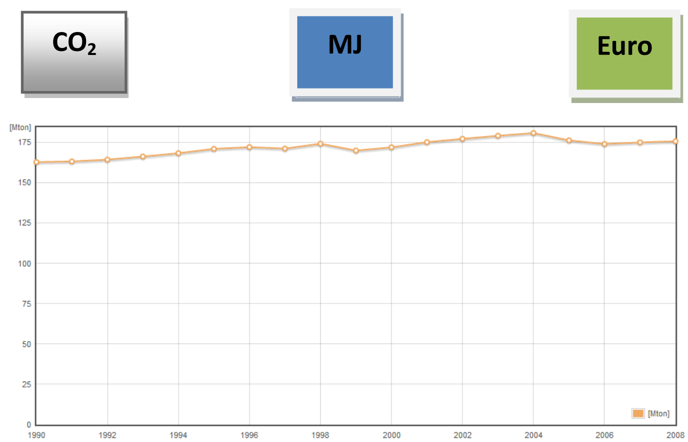


Figure 12: Analysis tool Energiescanner

Source: www.energiescanner.com (not yet publically available; June, 2012)

Energy feature

To counteract green washing it is also possible to analyze the energy use of the organization. For example green electricity has a first order emission factor of 0 gram CO_2/kWh. This results in a false picture of reality, because energy is still used. The "MJ" button is a feature that allows the user to analyze the organization on energy use as a more neutral unit. As energy carriers are normally presented in MJ/L, MJ/m^3, kWh the user gets a better feeling how much first order energy and ERE is really used.

Euro feature

The energy prices are volatile and steadily increasing in the last months (CBS, 2012). Reducing energy demand is therefore more and more interesting from a financial perspective. The "Euro" button is a feature that allows the user to analyze the costs involved regarding energy use. It provides quickly and easily an overview of which subjects consumes the most money. Investment opportunities can be analyzed regarding cost effectiveness next to energy effectiveness and reducing the carbon footprint.

Combination of features

The combination of getting insight in the carbon footprint, energy footprint and costs per part of the reporting company and subject(s) of the users own selection enables the reporting company to make better judgments.

Table 6: Data gathering for based judgments

	Data provided by the reporting company	Data provided by Eneriescanner		
	Net-Investment costs	**Carbon emission**	**Energy use**	**Variable costs**
	[Euro]	[Ton/year]	[GJ/year]	[Euro/year]
Current tech.	*Residual value*			
Project X				
Total				

** Subject can be of the head office, subsidiary or the whole reporting organization.*

The data in the table (+ Lifetime of the project and discount rate) above enables the reporting company to do economical analysis such as Return on Investment (ROI) calculations as well as CO_2 and energy abatement cost curves. A detailed example of how this information can be used is elaborated in chapter 5.2.

Standard reports

It is also possible to download standard reports in order to analyze the carbon and energy footprint. It is possible to download reports for the entire reporting organization or for the business parts separately. The advantage is that managers of different business parts can analyze their carbon footprint by themselves.

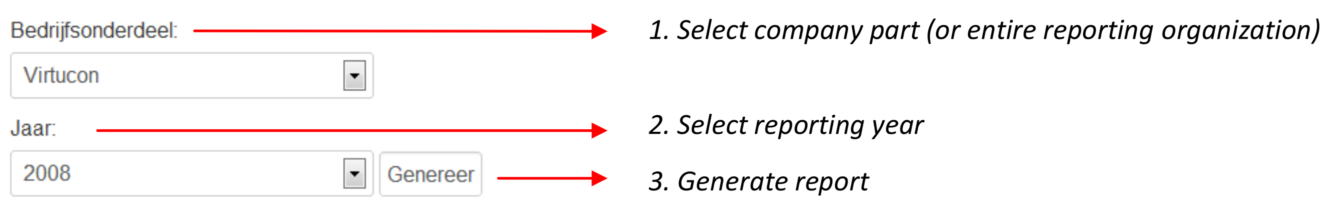


Figure 13: Screenshot download standard reports

Source: www.energiescanner.com

The standard reports contain the following information (translated from Dutch).

1. Background;
2. Measurement results;
   2.1 Carbon footprint (split per scope);
   2.2 Emissions, energy and variable costs;
   2.3 Monitoring;
3. Reduction targets;
4. Reduction efforts.

1. Background

In this section information is provided a non-expert needs to understand the standard report. The main subject that is dealt with in this section is the distinction between the different scopes as defined by the GHG Protocol.

2. Measurement results

For every scope a graph is generated with the results of the GHG emissions on the subject level. Every graph is supplemented with information so every reader understands what emission sources are allocated to the specific subject. The person responsible for filling in the activity data can add his own remarks below the graph (2.1). The next subchapter contains one large table with all aggregated data on subject level with *Energy use*, *Carbon emissions* and *Variable costs* (2.2). The last subchapter contains a graph with monitoring data on the developed of the total carbon emissions over time of the reporting company. The graph contains information on the selected reporting year including all previous years which contain activity data (2.3).

3. Reduction targets

This chapter contains one table with information regarding the reference year, reporting year and target year. The reference year contains the emissions of the first year in which activity data is filled in (classified as reference year). The reporting year contains the emissions of the selected reporting year. The target year contains information that is set by the reporting company. This information enables the reporting company to see whether or not they are on track on their reduction targets.

	Reference year 2005		Reporting year 2011		Target year 2020	
Scope 1	100	Ton CO2	95	Ton CO2	75	Ton CO2
Scope 2	50	Ton CO2	55	Ton CO2	30	Ton CO2
Scope 3	80	Ton CO2	70	Ton CO2	40	Ton CO2
TOTAL	230	Ton CO2	220	Ton CO2	145	Ton CO2

Figure 14: Setting reduction targets

Source: Standard report Energiescanner

4. Reduction efforts

The last chapter contains information that is written by an employee of the reporting company. In order to reach the targets set by the reporting company it is essential to have a reduction strategy. Information regarding the development of the strategy can be found on the website (reduction tab) and is further elaborated in the next section (4.2.4). The reduction efforts are practical steps the reporting company intends to execute.

4.2.4 Function: Reduce

Energiescanner is not able to provide a tailor made plan of action that identifies reduction opportunities. However, Energiescanner is able to provide all relevant data that is needed to develop an effective reduction strategy. The first step is to have a critical view at the performance of the reporting company.

Reduction strategy described on the website

Within Energiescanner the Trias Energetica method (Novem, 1996) is used as guidance for the development of a strategy for reducing the carbon and energy footprint of the reporting company.

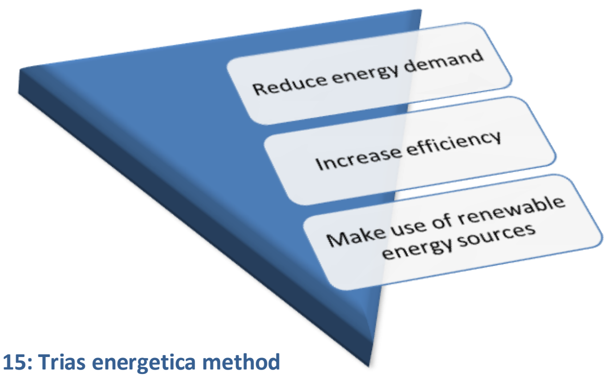


Figure 15: Trias energetica method

Source: Figure own design, method (Novem, 1996)

The first step is to reduce the total energy demand. This means a critical view on employee movements in vehicles or airplanes, electricity use (good indicator is to compare the electricity used at night versus the electricity use during the day; if the double meter is installed) etcetera. The second step is to increase the efficiency of subjects that use energy. Most likely the largest energy user and thereby carbon emitter is the car park. Lease cars have a relative short lifetime in a company and can therefore in a relatively short amount of time be replaced with more efficient ones. The last step is to make use of renewable energy sources. Installing solar panels on the roof or other actions can increase the use of renewables significantly.

Chain reduction

Doing business costs energy. Suppliers and customers use energy e.g. in the form of transport and distribution activities. For example instead of sending small batches of packages a few times a week it is also possible to send one large batch per week. This type of agreements may reduce scope 3 emissions and energy use significantly.

Reduction and cost savings

As described in the analysis part (4.2.3) and case study (5.2.1) reducing energy use can potentially save a lot of money. The method described in these sections is also described on the website.

Facts and discussion

For the interested user of Energiescanner some facts and discussions regarding carbon and energy accounting can be found. For example biomass accounting is not undisputed and is discussed here.

4.3 Development consistent database

In this chapter the database which will be used for carbon and energy accounting will be shaped. First the implementation of the guiding principles covered in the term consistency will be discussed (4.3.1). The next step is to determine emission factors (4.3.2) and energy factors (4.3.3) followed by the money factors (4.3.4). The fifth step is a framework on how the database will be designed (4.3.5) and finally the main data collection sources will be shown (4.3.6).

4.3.1 Consistency

The consistency of emission and energy factors is very important to have reliable results. Blok (2007) distinguishes multiple orders in which energy factors can be calculated. The table below shows an overview of these orders including a description of the order and the anticipated error level of the energy factors.

Table 7: Accuracy emission and energy factors

Order	Description	Error level
Zero order	Only final energy use	Unacceptable
First order	Including conversion losses[2]	<10%
Second order	Including conversion losses and mining and transportation losses	<5%
Third order	Including conversion losses, mining and transportation losses and energy required for the capital stock of the energy conversion process and operation and maintenance.	1 – 2%

Source: (Blok, K., 2007, p. 133)

Because energy use is almost in every situation directly correlated with carbon emissions the same distinction method can be used for carbon emissions. Within the GHG Protocol scope 1 emissions include only direct emissions emitted by the reporting company. As fossil fuels need to be extracted, processed and transported these emissions are correlated with the direct emissions and energy use of the reporting company. Every liter of fuel used (e.g. gasoline) by the reporting company is extracted, processed and transported and is therefore indirectly responsible for these emissions. Also the mining and transportation losses of electricity use (scope 2: Indirect emissions) must be reported in scope 3 (see Table 8). All activities within the energy supply side uses energy, this is called *Energy Required for Energy* or ERE. (Blok, K., 2007). In this report, GHG emissions resulting of ERE activities will be abbreviated into ERE_{CO2}; energy use of ERE activities will be abbreviated into just ERE. The difference between first and second order values is: First order value + $ERE_{(CO2)}$ = Second order value (see Figure 16 for a schematic overview). As from further on the ERE will be defined as percentage of the first order value. This results in the following formula: First order value * (1 + $\%ERE_{(CO2)}$) = Second order value. By limiting the accuracy of carbon emissions and energy use to second order values, Life Cycle Analysis (LCA) do not have to be taken into account. According to the ISO 14040.2 guidelines, an LCA is defined as: "*A systematic set of procedures for compiling and examining the inputs and outputs of materials and*

[2] Blok (2007), page 133: "*First order representation: fuel inputs are counted together with electricity inputs, taking into account conversion losses in electricity generation for these inputs*."

energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle." (GDRC, 2012). Including LCA's in this research would make it impossible to perform this research in the designated time schedule and would only increase the accuracy of the database with a few percentages.

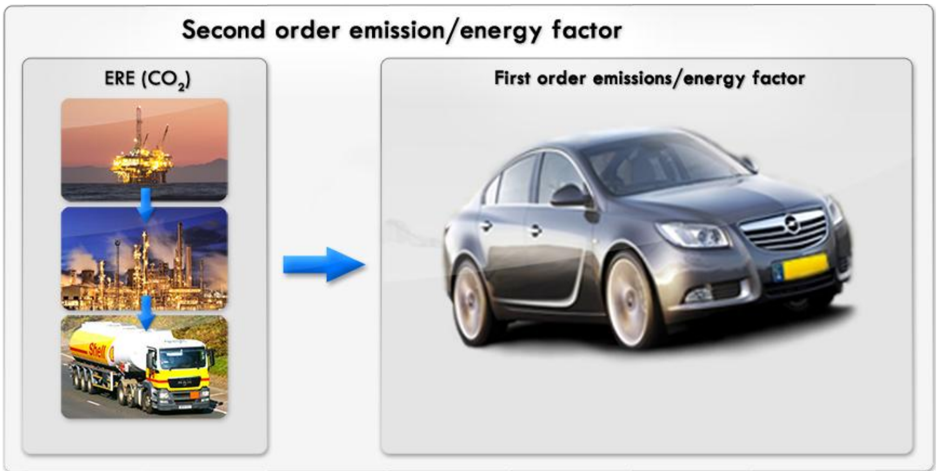


Figure 16: Schematic overview of the relationship between orders
Source: Figure own design

Link between ERE values and ERE_{CO2} values
ERE values and ERE_{CO2} values do not have to be equal. The relationship between the CO_2 emissions per unit of energy is different per form of energy [gram CO_2/MJ]. In the extraction, processing and transportation process multiple forms of energy is used to produce a specific type of fuel. This results in different ERE values for CO_2 emission factors and energy factors. For example gas is mainly distributed by pipelines, while gasoline is transported using trucks. Using pipelines for distribution requires far less energy than distribution by using trucks (Blok, K., 2007).

Used orders: GHG Protocol versus SKAO database
The database that is developed by SKAO contains only second order emission values. This mean that by using the SKAO database the total GHG emissions will be higher in scope 1 and scope 2 compared to the GHG Protocol (standard) database. Table 8 shows an overview of the used orders per scope for the standard database and the SKAO database.

Table 8: Order emission factors per scope GHG Protocol and SKAO

Scopes	GHG Protocol		SKAO
Scope 1	First order	ERE*	Second order
Scope 2	First order	ERE*	Second order
Scope 3	Second order		Second order

** reported in: Scope 3) Fuel- and energy related activities*

All $ERE_{(CO2)}$ values of the subjects defined in scope 1 and scope 2 are automatically allocated to scope 3, subject: 'Fuel- and energy related activities'. The reporting company cannot alter these values.

4.3.2 Determining CO_2 emission factors

The GHG Protocol is clear on how to deal with first and second order values, however SKAO does not follow this part of the protocol. As the factors showed in equation 1 are time depended and database dependent the following adjustments are made:

Equation 6: Adjusted formula GHG accounting tool

$$Activity\ data_{s,i} * (first\ order\ emission\ factor_{s,d,i} + (first\ order\ emission\ factor_{s,d,i} * \%ERE_r)) = GHG\ emission_s$$

<u>Legend</u>

s = Subject (e.g. scope 1, subject 1)
i = reporting year (e.g. 2011)
d = database (GHG Protocol or SKAO)
r =ERE rule[3]

CO_2 emission factor electricity

As for the calculation of the CO_2 emission factor of electricity multiple methods exists (Graus and Worrell, 2011) this will be discussed separately. The CO_2 emission factor or CO_2 intensity of electricity generation differs due to the difference in accounting method of combined heat and power generation. As power stations often generate electricity and heat it is difficult to allocate the fuel input for just the electricity generation and heat output. Graus and Worrell compare five methods as described below:

(1) power and heat generation method
$CO_2\ intensity = \sum(C_i I_i)/ \sum(P_i + H_i)$

(2) power generation method
$CO_2\ intensity = \sum(C_i I_i)/ \sum(P_i)$

(3) power loss factor method
$CO_2\ intensity = \sum(C_i I_i)/ \sum(P_i + sH_i)$

(4) substitution principle method
$CO_2\ intensity = \sum(C_i(I_i - H_i/r) / \sum(P_i)$

(5) exergy method
$CO_2\ intensity = \sum(C_i I_i)/ \sum(P_i + CaH_i)$

Legend
C_i = CO_2 emission factor per fuel source
I_i = fuel input per fuel source

P_i = power production per fuel source
H_i =heat output per fuel source
s = the power loss factor
r = the reference efficiency for heat generation
Ca = Carnot factor

The *power and heat generation method* (1) is used in multiple publications of e.g. the IEA (Graus and Worrell, 2011), (IEA, 2005). This method does not take into account the difference in quality of the state

[3] In case the standard database is chosen the ERE values are automatically allocated to scope 3 (subject 5 - fuel and energy related activities)

of the energy (electricity or heat) but deal with it equally. The *power generation method* (2) allocates all fuel input to electricity generation (heat generation is simply not taken into account).The *power loss factor* (3) method makes it possible to sum electricity generation and heat production. As already mentioned heat has a lower quality than electricity. By using a 'power loss factor' the quality of the heat generation is compensated and can be compared with electricity generation. The *substitution principle method* (4) takes into account the fuel that would have been needed if the heat was generated separately. The reference efficiency for the generation of heat is around 90%. The *exergy method* (5) calculates all energy flows as exergy. This method will not be elaborated further because of the similarity with the power loss method (Harmsen and Graus, 2012). The GHG Protocol subscribes: "*It is important to choose the emission factor most relevant to your activity data.*" (Putt del Pino et al, 2006, p. 34). In the Netherlands a relatively large share of electricity is produced by CHP plants (Energie, 2011), this implies that method 1 and 2 will not result in a reliable CO_2 intensity. Within this research a slightly adapted version of the power loss method will be used to calculate the CO_2 intensity of electricity.

As a consumer you can choose between grey or green electricity; this means that the emission factor of electricity should accordingly be calculated. This implies that sustainable energy sources will be excluded while using the power loss method. By differentiating between green and grey electricity use the residual mix is not affected when more or less people change their type (grey or green) of electricity. From a practical point of view this makes it much easier to calculate the emission/energy factor of electricity. At the moment there are no guidelines available to calculate the CO_2 intensity of green electricity; the website of the GHG Protocol states on this subject: "*developing drafts which will be available for public comment in Summer, 2012. Final publication of the (GHG Protocol Power Accounting*) *Guidelines is scheduled for late Fall, 2012*". The WRI postponed publishing the drafts which have implications for this research as they cannot be incorporated. Instead multiple other sources regarding the calculation of intensity values of green electricity will be evaluated. These sources will be used as substitute for the calculations until the GHG Protocol publishes their guidelines.

ERE_{CO2} electricity losses

Power plants have upstream and downstream energy losses in the process of converting fossil fuels into electricity. Upstream energy losses are losses in the form of extraction, production & transportation (EP&T) of the fossil fuels to the power plant. Downstream energy losses are losses in the form of transport and distribution (T&D) losses of the produced electricity from the power plant to the end user. For the end user both EP&T losses and T&D losses can be seen as upstream losses and must be reported in scope 3. The figure below represents four perspectives, per perspective it is shown which emissions should be allocated to which scope. Direct emissions (scope 1) can never be double counted over the value chain.

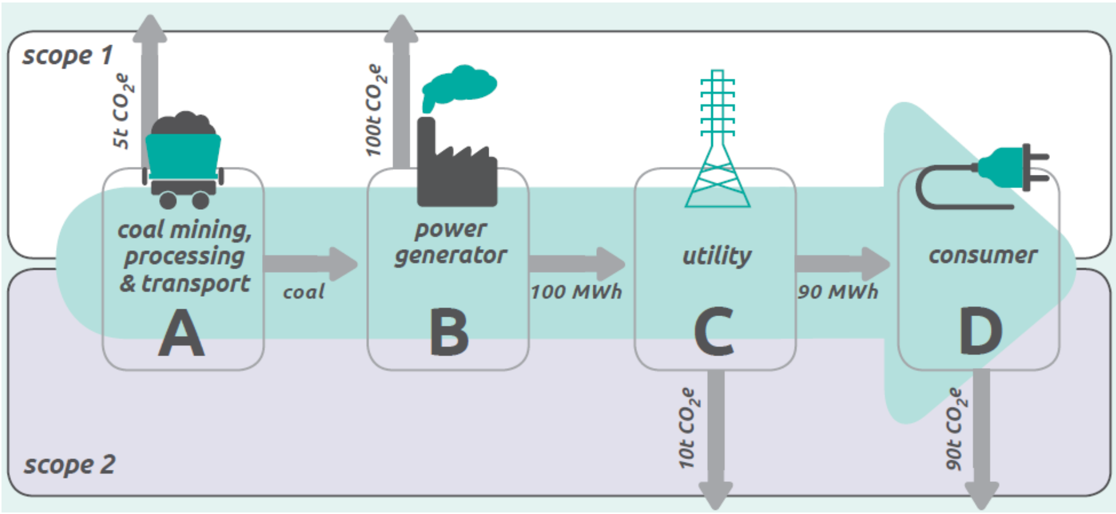


Figure 17: Allocating emissions across an electricity value chain
Source: (Bhatia et al, 2011, p. 42)

Coal mining, processing & transport perspective (A)
According to the GHG Protocol 5 ton of CO_2 must be allocated to scope 1 and 100 ton CO_2 to scope 3 (subject: use of sold products).

Power generator perspective (B)
In the second step of the value chain 100 ton CO_2 should be allocated to scope 1 and 5 ton CO_2 to scope 3. The energy required to operate the power plant is from the power generator perspective allocated to scope 1. Normally the own consumption of a power plant is around 3% and 4% of the production (Harmsen and Graus, 2012).

Utility perspective (C)
The T&D losses can be seen as consumed energy by the utility and must therefore reported in scope 2. For scope 3 emissions 10% of the EP&T emissions must be allocated (0.5 ton CO_2) and 90 ton CO_2 as sold products.

End consumer perspective (D)
From the end user perspective (target group of this research) 0 ton CO_2 should be allocated to scope 1, 90 ton CO_2 to scope 2 and (90% of 5 ton CO_2 EP&T losses + 10 ton T&D losses) 14.5 ton CO_2 in scope 3, subject: Fuel- and energy related activities (more info, see chapter 4.3.1).

4.3.3 Determining energy factors

Most calculation tools only take GHG emissions into account [ton CO_2]. Also the GHG Protocol only requires reporting GHG emissions. The problem with calculating just CO_2 emissions is that it not necessarily stimulates taking energy efficiency measures. In general the CO_2 emissions in service sector companies come mostly from three sources namely transport (commuting, business travel), heating the building and electricity use. For example a company can just switch to a green electricity supplier and lower their carbon footprint significantly, without really doing something. Providing data in energy units gives another relevant perspective. Therefore this calculation tool also provides information on energy use [GJ]. The use of refrigerants is the only exemption as refrigerants have no energy intensity but only an emission factor. In order to calculate the energy use of a subject the following equation has been designed:

Equation 7: Formula energy accounting

$$Activity\ data_{s,i} * (first\ order\ energy\ factor_{s,d,i} + (first\ order\ energy\ factor_{s,d,i} * \%ERE_r)) = energy\ use_s$$

Legend
s = Subject
i = reporting year
d = database
r =ERE rule

4.3.4 Determining money factors

Service sector companies are commercial and therefore speak the language of money. For non-experts it is hard to have a feeling with numbers with unfamiliar units. Recalculating energy use in euro's spent [Euro] can trigger the entrepreneur to take energy efficiency measures. Only variable costs[4] of the subjects are taken into account as it provides information on the effects of implementing efficiency measures. The money involved will only be applicable for scope 1 and scope 2 emissions, due to the complexity and boundary problems of the subjects in scope 3. Return on investments (ROI) calculations regarding investment costs in energy efficiency measures versus decreasing variable costs are not available in the tool. As the tool provides insight on the variable cost side it is rather easy to calculate the maximum investment costs a company is willing to invest (when the maximum ROI determined by the company). In order to calculate the money spent on a subject the following equation has been designed:

Equation 8: Formula money spend on energy accounting

$$Activity\ data_{s,i} * \ money\ intensity\ factor_{s,i} = \text{money spent}_s$$

The same legend for Equation 7 can be used for Equation 8*. Activity data* in e.g. [L/year] times the *money intensity factor* in [Euro/L] resulting in total *money spent* [Euro/year].

[4] Variable costs are calculated excluding VAT but including energy taxes

4.3.5 Database framework

In order to understand the results, this chapter provides a framework on how the data is presented in chapter 4.4.

Emission factors and energy intensities

The most important data is of the main fuels. For every basic fuel the *first order CO_2 emission factor* and accompanied *ERE_{CO2}* is presented as well as the *first order energy intensity* and accompanied *ERE.*

1. Fuels

Table 9: Presenting 'fuel data'

Fuel	First order CO2 Emission factor	ERE_{CO2}	First order energy intensity	ERE
1. Fuel type	[gram CO_2/Liter] or [gram CO_2/m^3]	*[%]*	[MJ/Liter] or [MJ/m^3]	*[%]*

Next to company or privately owned cars it is possible to use public transport for business travel and commuting. As public transport is powered by one of the liquid or gaseous fuels only the amount of these fuels is needed to calculate the CO_2 emission and total energy use. Within this research only the energy use within the operational phase of transport vehicles will be taken into account. The reason is that the data needed of the other phases within a Life Cycle Assessment (e.g. production of the vehicle, construction infrastructure, maintenance vehicle and infrastructure and lastly disposal of the vehicle) is not in harmony with the principles of the GHG Protocol. It is expected that the data is not complete, not consistent, not transparent and likely to be inaccurate. As there is a difference between basic fuels such as diesel and gasoline versus biofuels, these will be split in the result section.

2. Electricity

Table 10: Presenting 'electricity data'

Grey Electricity	First order CO2 Emission factor	First order energy intensity	$ERE_{(CO2)}$
Year	[gram CO_2/kWh]	[MJ/kWh]	*[%]*

Green Electricity	First order CO2 Emission factor	ERE_{CO2}	First order energy intensity	ERE
Type	[gram CO_2/kWh]	*[%]*	[MJ/kWh]	*[%]*

As there is a large difference between grey and green electricity the results will be split. The first order CO_2 emission factor and the first order energy factor of grey electricity are different every year. This is due to shifts in shares of fuel use in different types of power plants and possible changes in efficiency (implemented efficiency upgrades or opening new power plants). As the ERE values for CO_2 and energy are equal, only one value will be presented. For green electricity it is important to make a distinction between the different types of renewable energy sources. Every type of renewable energy source has its own $ERE_{(CO2)}$ values.

Transport related data (3,4,5 and 6)

Table 11: Presenting 'transport data'

Type	Energy (First order)	Fuel type
3. Public transport	[pkm*/Liter or pkm/kWh]	Name
4. Cars	[km/Liter]	Name
5. Own transport	[tonkm**/Liter]	Name
6. External transport (freight)	[piece kg/Liter]	Name

** pkm is passenger kilometer, 1 pkm is 1 passengar moved 1 km.*

*** tonkm is ton kilometer, 1 tonkm is 1 ton of goods moved 1 km*

3. *Public transport*

Data will be presented in pkm/Liter or when the vehicle is powered with electricity in pkm/kWh. All data is adjusted by average occupancy of the vehicle. The fuel type is specified so by simple conversion it is possible to calculate from first order energy intensity to first order CO_2 emission factor.

4. Cars

When specific data of the amount of fuel used per car is lacking it is possible to enter the distance traveled (in kilometers) of the vehicle. This method is less accurate but still accepted within the GHG Protocol. To calculate the total emission of the car with just the distance an estimate has to be made of the efficiency of the car [km/L]. The efficiency of the car is correlated with the size of the car. Within this research a distinction will be made between small, medium and large sized cars.

5. Company transport vehicles

It is possible that the company owns transport vehicles such as vans, trucks or ships. The most accurate method to calculate emissions and energy use is again by the amount of fuel used. When this data is lacking it is possible to estimate the amount of ton kilometers per type of transport vehicle.

6. Mail and packages

Not all companies have their own transport vehicles but outsource their freight to external parties. It is impossible to track all sent mail and packages and calculate the emissions and energy use. To overcome this problem PostNL (national and international shipments) developed a carbon calculator (PostNL, 2012) to calculate the average emissions per kg of freight send within the Netherlands, within the EU or outside the EU.

7. Refrigerants

Table 12: Presenting 'refrigirant data'

Refrigirant	First order CO2 Emission factor	ERE $_{CO2}$
7. Refrigirant type	[gram CO_2/Liter]	*[%]*

Only the CO_2 emission factor of refrigerants is taken into account, because energy values are in this case not relevant.

8. Other

Table 13: Presenting 'other data'

Fuel	First order CO2 Emission factor	ERE $_{CO2}$	First order energy intensity	ERE
8. Fuel type or energy source	[gram CO_2/Liter, kg, GJ, m^3]	*[%]*	[MJ/Liter, kg, GJ, m^3]	*[%]*

The most common activities which are related to energy use and thereby GHG emissions within service sector companies are described in point 1 – 7. However it is always possible that there is a service sector company in the Netherlands which uses a different type of fuel (solid, liquid, gas) or energy source.

Prices

It is expected that the user of the calculation tool is aware of the variable energy costs regarding the subject. When this data is lacking a database with average prices over the relevant year will be used to fill this data gap. The user is obliged to enter data excluding VAT.

4.3.6 Main data collection sources

The calculation tool will be designed especially for Dutch companies, therefore all emissions factors, energy factors and prices should be applicable for the Dutch situation. The table below shows the most important sources for data collection. These sources contain information regarding first and second order emission/energy factors that are needed to develop the database. Due to contractual differences prices can vary per company for e.g. electricity or gas. In many situations the reporting company is therefore responsible for this data.

Table 14: Main sources emission factors, energy intensities and prices

Data needed	Emission factors	Energy factors	Prices
1. Fuels	IPCC (1) Energy Analysis (2) AgentschapNL (3)	IPCC (1) Energy Analysis (2) AgentschapNL (3)	Reporting company/ CBS (4a)
2. Electricity	CBS (4b)	CBS (4a)	Reporting company/ CBS (4a)
3. Public transport	STREAM (5)	STREAM (5)	User
4. Cars	SKAO (6)	SKAO (6)	Reporting company/ CBS (4a)
5. Own transport	STREAM (5)	STREAM (5)	Reporting company
6. External transport (freight)	STREAM (5)	STREAM (5)	Reporting company
7. Refrigerants	SKAO (6)	n/a	Reporting company
8. Other	STREAM (5), PostNL (7)	STREAM (5), PostNL (7)	Reporting company

Sources: 1. (IPCC, 1996)*, 2.* (Blok, K., 2007)*, 3* (AgentschapNL, 2011) *4a.* (CBS, 2012) *4b.* (CBS, 2012) *and* (Harmsen and Graus, 2012)*, 5.* (STREAM, 2008) *6.* (SKAO, 2012)*, 7.* (PostNL, 2012)

Sources as STREAM, SKAO, AgentschapNL, CBS and PostNL are all institutions or research centers with a focus on The Netherlands and therefore very useful for this research.

4.4 Database values

As already mentioned the tool consists of two databases from which the user can choose its preferred database. The results of the first database that will be shown and justified is of the GHG Protocol.

4.4.1 Fuels

At the moment biofuels are not common within The Netherlands. Only small quantities are used each year compared to basic fuels such as motor gasoline and diesel. As there is a large difference on how they must dealt with from an accounting perspective they are split into two tables (Table 15/Table 16).

Table 15: Basic fuel values

		First order CO2 Emission factor		ERE_{CO2}	First order energy intensity		ERE
1	Motor gasoline	2,287[1]	g/L	*18.0%*[1]	33.0[1]	MJ/L	*12.0%*[3]
2	Diesel fuel	2,668[1]	g/L	*19.2%*[2]	36.0[3]	MJ/L	*12.0%*[3]
3	LPG	1,704[1]	g/L	*13.0%*[4]	27.0[3]	MJ/L	*12.0%*[4]
4	Kerosene	2,517[1]	g/L	*19.2%*[2]	35.0[3]	MJ/L	*12.0%*[3]
5	Heavy fuel oil	2,786[1]	g/L	*14.6%*[2]	36.0[3]	MJ/L	*12.0%*[3]
6	Natural gas	1,776[1]	g/m^3	*6.4%*[4]	31.7[5]	MJ/m^3	*3.0%*[3]

Sources: 1. (IPCC, 1996) 2. (STREAM, 2008) 3. (IEA, 2005) 4. (EUCAR & CONCAWE & JRC/IES, 2006) *5. (TNO, 2006)*

The ERE_{CO2} values of motor gasoline, diesel fuel, kerosene and heavy fuel oil are derived from absolute values provided by Stream. These values are; motor gasoline: 12,5 g CO_2/MJ, diesel fuel: 14,2 g CO_2/MJ, kerosene: 13,8 g CO_2/MJ and heavy fuel oil: 11,3 g CO_2/MJ. The ERE_{CO2} values of LPG and natural gas are derived from a study Well-to-tank report of the EU. These values are 8,2 g CO_2/MJ for LPG and 3,59 g CO_2/MJ for natural gas. The sources on which the ERE values are based all published specific values (except for LPG value, worst case 8,0 – best case 8,4 g CO_2/MJ), while it is assumed that these values are an average within a certain range. Only the book of K. Blok (2007) published a range for the energy ERE values; coal (4 – 10%), oil products (8% - 15%) and natural gas (1% - 5%).

Table 16: Biofuel values

		First order CO2 Emission factor		ERE_{CO2}	First order energy intensity		ERE
7	Bioethanol[5]	0	g/L	*841 g/L*	21.2	MJ/L	*57.3%*
8	E85[5]	343	g/L	*777 g/L*	23.0	MJ/L	*47.4%*
9	Bio-diesel[5]	0	g/L	*1,708 g/L*	33.0	MJ/L	*56.0%*
10	Biogas[5]	0	g/m^3	*759 g/m^3*	35.5	MJ/m^3	*56.0%*

5. Elaborated in Biofuel values (next section)

The values for biofuels are based on own calculations. At the moment there is still no consensus on guidelines on how to account for biofuels. The guidelines are controversial as they can have major impact on policy concerning biofuels. More information about the discussion of biofuels can be found in the discussion section at the end of this report. Within the next section the justification of the values as presented in Table 16 will be elaborated.

Biofuel values

There is still no consensus in scientific literature on how to deal with biofuels (Malça et al, 2004), (Whittaker et al, 2011) (Hoefnagels et al 2010) (Elsayed et al, 2003). The justification of the used values in this research will be elaborated in this section. Within IEA statistics unprocessed usable fossil fuel (crude oil) is seen as an energy carrier, while unprocessed biofuels is seen as raw material (Figure 18).

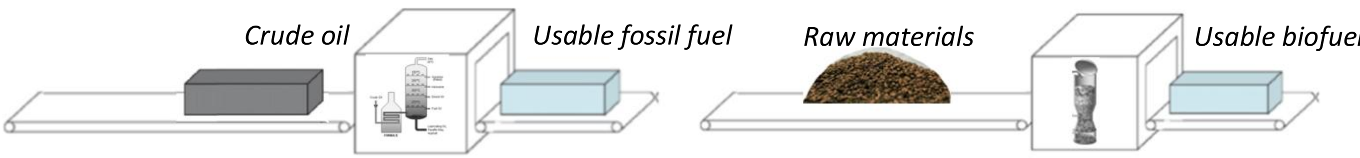


Figure 18: Dealing with primary energy carriers,
Source: Design figure derived from (Harmsen et al, 2011b)

The energy balance of fossil fuels is different because of this phenomenon. For example sugar beets need to be processed before it can be used as usable biofuel (bioethanol). The amount of raw materials that is needed is to produce bioethanol is relatively high, because not all biomass of the sugar beet can be converted into bioethanol. Not all types of biomass need to be converted into useable biofuel. For example woodchips can be directly used in coal fired power plants as co-firing. These woodchips are therefore treated as energy carrier, because they are useable biofuel. Within energy statistics the total amount of used crude oil is accounted as primary energy while for biofuels the raw materials is not accounted as primary energy. Wasting biomass in the form of raw materials is therefore not an issue as it is not accounted for.

Table 17: EP&T values derived from biofuel GHG calculator

	Biodiesel from Rapeseed		Biogas (CNG) from Municipal organic waste		Ethanol from Suger beet	
	Energy use (per MJ)	GHG emissions (g/MJ)	Energy use (per MJ)	GHG emissions (g/MJ)	Energy use (per MJ)	GHG emissions (g/MJ)
Feedstock production	0.17	28.8	0.00	0.00	0.08	11.5
Transport actions	0.02	1.4	0.06	2.8	0.04	2.3
Conversion operations	0.37	21.6	0.50	18.5	0.46	26.3
Total	**0.56**	**51.8**	**0.56**	**21.4**	**0.57**	**40.1**

Source: (NL Agency Ministry of Infrastructure and the Environment, 2011)

Table 17 is derived from a biofuel GHG calculator (version 3.6, Excel) developed by two consultancy offices (Sogeti and Ecofys) commissioned by the Dutch ministry of Infrastructure and the Environment. The methodology they used is described in Annex V.C of the Renewable Energy Directive (2009/28/EC) (RED) and in Annex IV.C of the Fuel Quality Directive (2009/30/EC) (FQD). According to the disclaimer embedded in the tool: "the *variation in the outcome of the calculation is at best +/-15% (This means that a 45% greenhouse gas emission reduction indicates a reduction between 30% and 60%)."* Next to the variation of outcome within the RED procedure; '*sensitivity analysis shows that the choice of the allocation procedure has a major influence on the results*' (Malça et al, 2004). This study found a variation of 50% depending on the allocation method used. The 'feedstock production', 'transport actions' and 'conversion operations' (see Figure 19, example of a biomass gasification plant) are all subjected to the ERE as these are not direct emissions from the end user perspective.

Table 18: First order energy factors biofuels

	First order energy factor	
Biodiesel	33.0	MJ/L
Biogas	35.5	MJ/m^3
Ethanol	21.0	MJ/L
Ethanol (85%)	*18.0*	*MJ/L*
Motor gasoline (15%)	*5.0*	*MJ/L*
E85	23.0	MJ/L

Source: (Elsayed, 2003)

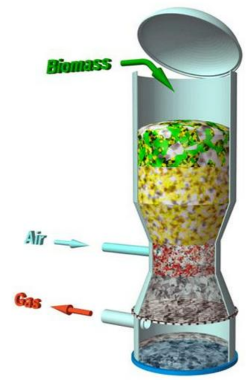


Figure 19: Biomass converter
Source: (Zafar, 2012)

Combining the data of the *first order energy factors* shown in Table 18 and the 'Energy use (per MJ)' and 'GHG emissions (g/MJ)' values shown in Table 17 the ERE and ERE_{CO2} values can be calculated (results shown in Table 16).

4.4.2 Electricity

Grey electricity

Table 19: Grey electricity values

Grey	First order CO_2 Emission factor[1]		First order energy intensity[1]		$ERE_{(CO2)}$[2]
2005 and before	620	g/kWh	9.66	MJ/kWh	*9.5%*
2006	610	g/kWh	9.57	MJ/kWh	*9.6%*
2007	612	g/kWh	9.38	MJ/kWh	*9.6%*
2008	595	g/kWh	9.52	MJ/kWh	*9.7%*
2009	555	g/kWh	9.29	MJ/kWh	*9.6%*
2010	559	g/kWh	9.20	MJ/kWh	*9.4%*
2011	559	g/kWh	9.20	MJ/kWh	*9.4%*
2012	559	g/kWh	9.20	MJ/kWh	*9.4%*

Source: 1. (CBS, 2011) and (Harmsen and Graus, 2012) 2. Elaborated in Energy and CO_2 ERE values grey electricity (next section). Values excluding sustainable energy production, excluding T&D losses, including own consumption of the power plants.

The fossil energy mix for the production of electricity (2010) in the Netherlands is mostly derived from gas fired power plants, followed by coal fired power plants (CBS, 2012). Nuclear and other fueled power plants have a minor share in the total energy mix in the Netherlands. The Energy Performance of Buildings Directive (EPBD) uses an efficiency value of 39% (9.22 MJ/kWh) (EPBD, 2008). This value is comparable with the values shown in Table 19. Another approach that could be used in this section is the method developed by the NMA, called *Stroometiket*. (NMA, 2005). Since 2005 energy suppliers are committed by the NMA (Dutch competition authority) to calculate their CO_2 emission factor (Stroometiket, 2012). Stroometiket subscribe that every electricity supplier in The Netherlands is obliged to report their energy mix they supply to their customers, including the carbon intensity [gram CO_2/kWh] related. A closer look at the published energy mix versus the published carbon intensity of certain energy suppliers revealed inconsistencies and values that cannot be realistic. Stroometiket is therefore not used to determine grey electricity values.

Determining $ERE_{(CO2)}$ values of grey electricity

The estimated extraction, production and transportation (EPT&T) losses (Blok, K., 2007) can be found in Table 20. In 2010 the fossil based energy mix in Dutch power plants was: (CBS, 2012).

Table 20: EP&T values fossil based energy mix of the Netherlands (2010)

	Fossil fuels as total[1]	EP&T[2]	Share EP&T
Coal	35.5%	7%	2.5%
Gas	52.9%	3%	1.6%
Nuclear	7.1%	12%	0.9%
Other	4.6%	5%	0.2%
	100.0%		**5.1%**

Source: 1. (CBS, 2012) *2. (Blok, K., 2007)*

Transport and distribution losses of electricity in the electricity net are recorded every year (CBS, 2012). The T&D losses and the total upstream losses of electricity can be found in Table 21.

Table 21: Upstream losses electricity end user perspective

	EP&T losses	T&D losses[1]	Total $ERE_{(CO2)}$
2005	5.1%	4.4%	9.5%
2006	5.1%	4.4%	9.6%
2007	5.1%	4.4%	9.6%
2008	5.1%	4.6%	9.7%
2009	5.1%	4.4%	9.6%
2010	5.1%	4.3%	9.4%
2011*	5.1%	4.3%	9.4%
2012*	5.1%	4.3%	9.4%

** Data not yet available (used values same as 2010)*

Source: 1. (Harmsen and Graus, 2012)

Disclaimer grey electricity values

The values presented in Table 19 may result in a false sense of certainty. It is very hard to determine which factors should be taken into account and which are not to be taken into account. For example import of electricity is not considered because the origin of the imported electricity is only tracked on national level (Belgium, Germany, and Norway). The same applies for the export of electricity as it is unknown which electricity (from a specific power plant or windmill) is exported. The figure below represents a schematic overview of the Dutch situation in 2011. The import and export of electricity is very volatile over the years. The import of electricity was 90 PJ in 2008, 56 PJ in 2009, 56 PJ in 2010 and 74 PJ in 2011. The export of electricity was 33 PJ in 2008, 38 PJ in 2009, 46 PJ in 2010 and 42 PJ in 2011. Import and export data cannot be forecasted as it is dependent on multiple variables.

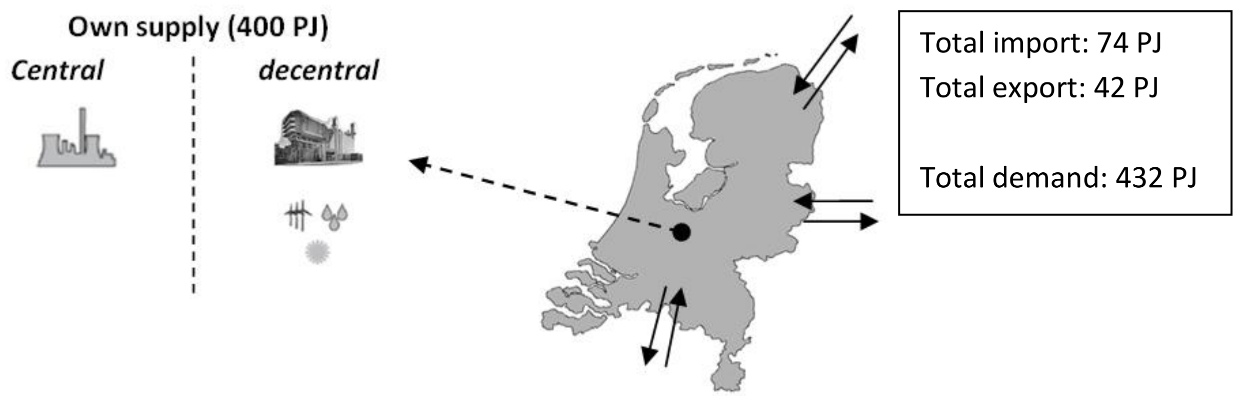


Figure 20: Schematic overview Dutch electricity supply and demand, year 2011
Source: Figure own design; data (CBS, 2012)

The total electricity demand of the Netherlands is 432 PJ (2011) (or 120 TWh[5]). As described in the method section the used method to calculate the CO_2 intensity per kWh results in a broad range of values. The power and heat generation method (used by the IEA) would result in 390 gram CO_2 per kWh, while the power only method would result in 626 gram CO_2 per kWh (difference of 161%) (Harmsen and Graus, 2012). Values excluding sustainable energy production, excluding T&D losses, including own consumption of the power plants. The yearly fluctuations in CO_2 intensity can partly explained due to for example maintenance in a coal fired power plant. This would result in a larger load factor for e.g. a gas fired power plant (lower emission factor than coal). The question is whether or not these (small) fluctuations are relevant for the reporting company (end consumer of electricity). The core of the assessment is to take action in the form of determining a reduction strategy. Reduction efforts at the production side should not lower the urge of the end consumer to reduce its demand.

Note 1: It is not feasible to calculate the grey electricity values every year. This calculation exercise is time consuming and it takes several years before all data of the current year is available. At this moment not all required data for 2011 and 2012 is available; therefore the values of 2010 are adopted.

Note 2: If the reporting company produces electricity by itself the fuel use in the generator is reported in scope 1. This automatically eliminates T&D losses, which is correct as the electricity is used on site.

[5] 432 PJ_{elec} (432×10^{15} J) is equal to 120 TWh (120×10^{9} kWh)

Green electricity

The *GHG Protocol Power Accounting Guidelines* concerning the calculation of the CO_2 intensity of electricity is not yet published, therefore other scientific sources will be used.

Table 22: Green electricity values

Green	**First order CO_2 emission factor**	**ERE_{CO2}**	**First order energy intensity**	**ERE**
Wind	0 g/kWh	*0.0 g/kWh*	3.6 MJ/kWh	*4.3%*
Water	0 g/kWh	*0.0 g/kWh*	3.6 MJ/kWh	*4.3%*
Solar	0 g/kWh	*0.0 g/kWh*	3.6 MJ/kWh	*4.3%*
Electricity out of landfill gas	0 g/kWh	*256.6 g/kWh*	12.0 MJ/kWh	*60.3%*
Electricity out of biomass	0 g/kWh	*621.0 g/kWh*	12.0 MJ/kWh	*60.1%*
Other green	0 g/kWh	*372.3 g/kWh*	8.4 MJ/kWh	*37.8%*

Source: Elaborated in sections below

First order CO_2 emission factor green electricity

According to the Stroometiket 100% green electricity suppliers, such as Greenchoice, have a carbon emission factor of 0 g/kWh (Energieprijsvergelijkers, 2012). This implies that the first order emission factor of green electricity is 0 g/kWh.

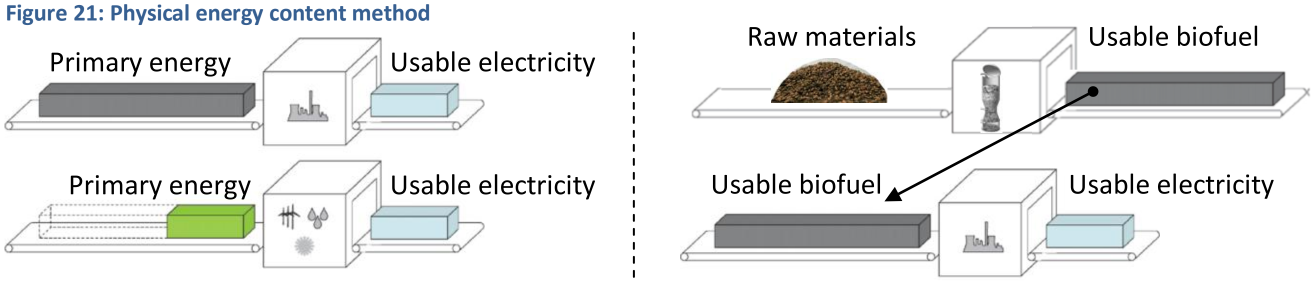
ERE_{CO2} green electricity

As this research does not take Life Cycle Assessments into account the ERE values of wind, water and solar power is zero. For electricity out of biomass is a bit more complex as already described in the biofuels values in section 4.4.1 Fuels. *Electricity out of landfill gas* is linked to biogas. *Electricity out of biomass* is linked to biodiesel and *other green* is calculated using the green energy mix. The calculations are based on ERE values of first order energy intensities.

First order energy intensity green electricity

According to the *physical energy content method*, which is used by Eurostat and the IEA (IEA, 2005) (Eurostat & European Commission, 2011), one unit of primary energy can be converted to one unit of electricity for water, wind and solar energy. This means a conversion efficiency of 100% is used. For fossil energy this conversion efficiency is around 40% (2,5 units of primary energy converted into 1 unit of electricity), see Figure 21.

Figure 21: Physical energy content method



Source: (Harmsen et al, 2011b)

Source: Figures own design

The conversion of biomass into electricity according to the physical energy content method is different. The primary form of biofuel is raw material (as already described this is not seen as an energy carrier, (see 4.4.1). However as there is still much debate around how to deal with biomass and the guidelines of the GHG protocol are not yet released, choices have to be made. Within this research usable biomass will be treated as primary energy. The advantage is that comparison between grey and green electricity is more straight-forward. The average efficiency of biomass power plants is 30% (ECN, 2004), used for *Electricity out of landfill gas* and *Electricity out of biomass. Other green* must be split into the parts on which the different forms of renewables contribute to green electricity. Within The Netherlands 60% of renewable energy is produced with the use of biomass (CBS, 2012), 85% biogenic and 15% biogas; the other 40% is produced with wind, water and solar power.

Energy ERE green electricity

Wind, water and solar power lose only energy during transport and distribution. As shown in Table 21 this value is 4,3%. The other green electricity types contain biomass, which is therefore much higher.

Table 23: ERE values green electricity

Type	EP&T losses	T&D losses	Total ERE
Wind power	0.0%	4.3%	4.3%
Water power	0.0%	4.3%	4.3%
Solar power	0.0%	4.3%	4.3%
Electricity out of landfill gas	56.0%	4.3%	60.3%
Electricity out of biomass	55.8%	4.3%	60.1%
Other green	33.5%	4.3%	37.8%

The relations between the ERE values of the biomass fuels and ERE values of green electricity is the same as described in the ERE_{CO2} green electricity.

Disclaimer green electricity values

Determining the emission factors and ERE values of green electricity is difficult and controversial. For example the emission factor database of the CO_2 prestatieladder used for solar power is 80 gram CO_2/kWh (SKAO, 2012), while the organization Milieucentraal uses 50 gram CO_2/kWh (Milieucentraal, 2012). These values presented by the CO_2 prestatieladder and Milieucentraal are based on so called Life-cycle-assessment (LCA) studies (there are no direct emissions when solar panels are converting solar energy into electricity). For a solar panel such an LCA relies on values based on the extraction, production and transportation of the raw materials, production of the intermediate products, assembly of product, distribution, maintenance and finally the energy needed to dispose the product. The parameters are time and place specific (varies per manufacturer) and therefore highly debatable. To be accurate for an assessment tool as Energiescanner an emission factor should be calculated per solar panel manufacturer and updated every year. For this reason this research does not take LCA studies into account. Also this would imply that all other values in this research, such as fossil power plants, public transportation (construction of infrastructure), cars etc. should take this into account. Publishing the guidelines for green electricity by the GHG Protocol can have large implications for policy makers. It can make or break the implementation of a green energy technology. Caution and precision is therefore very important. The system of circulating drafts of the protocol is preferable and may lead to a broader base for the guidelines.

4.4.3 Public transport

The first order energy intensity of public transport is for a large part depended on the occupation rate of the vehicle. According to Milieucentraal it is desirable to use public transport outside peak hours (Milieucentraal, 2012). This is because the occupation rate in off-peak hours is much lower and therefore less efficient per passenger kilometer. Also the weight of the passenger/baggage is of importance for calculating the first order energy intensity of public transport. In practice it is impossible to track the occupancy rate and the average weights of passenger (incl. baggage) in public transport vehicles; therefore average occupancy rates and weights are used. As most energy is used during the land and take-off (LTO) phase of airplanes, the first order energy intensity becomes more efficient (more passenger kilometers per liter) as the distance becomes longer (STREAM, 2008).

Table 24: Public transport

Type	First order energy values		Fuel type	
1. Bus (city/region)	34.7	pkm/L	*Diesel fuel*	
2. National rail	10.8	pkm/kWh	*Electricity*	
3. International rail	11.7	pkm/kWh	*Electricity*	
4. Tram	6.8	pkm/kWh	*Electricity*	
5. Tube	7.2	pkm/kWh	*Electricity*	
6. Airplanes	(ex Radiative Forcing)			Radiative Forcing
0 -1.000 km	17.2	pkm/L	*Kerosene*	2.1
1.000 -2.000 km	23.7	pkm/L	*Kerosene*	2.1
2.000 -5.000 km	25.5	pkm/L	*Kerosene*	2.1
5.000 -9.000 km	31.3	pkm/L	*Kerosene*	1.7
9.000 -20.000 km	28.8	pkm/L	*Kerosene*	1.7

Source: (STREAM, 2008)

Radiative Forcing

In aviation the contribution to the greenhouse gas effect is higher than just CO_2 emissions. Especially condensation trails contribute a large share. This *radiative forcing* effect is largely depended on altitude and weather conditions. The IPCC uses a radiative forcing of 2.7 (IPCC, 1999). According the report of STREAM it is expected that this value is overestimated. They state that a radiative factor of 2.0 is more likely, however after recalculating their results different radiative forcing values pop up. As radiative forcing is still under debate the user of the developed assessment tool can choose whether or not the user takes this into account. This is in line with other already available calculation tools. Important to notice is that the radiative forcing has no effect on the first order energy intensity because one liter kerosene does not have miraculously an increased caloric value when flying in the air.

4.4.4 Cars

The first order energy values according to STREAM is 12.3 km/L for gasoline cars, 14.9 km/L for diesel cars and 10.9 km/L for LPG cars. As these values are almost equal with the average values of the SKAO database, the more extensive list of SKAO is used. Note that source of the transport data of SKAO is also STREAM. As expected the efficiency values of the cars decreases with the size of the engine. The values showed in Table 25 are good estimates for the efficiency of different sized cars. However, the driver of the car also influences the efficiency of the car (economic driver or not) it is more desirable that the consumed amount of fuel is kept record. If only the distance travelled per fuel type is known this data will be used in the calculation tool.

Table 25: Cars

Type	Size	First order energy values		Fuel type
Car	< 1.4 ltr	15.0	km/L	*Gasoline*
	1.4 – 2.0 ltr	12.6	km/L	*Gasoline*
	> 2.0 ltr	9.1	km/L	*Gasoline*
	average	12.9	km/L	*Gasoline*
	< 1.7 ltr	20.2	km/L	*Diesel*
	1.7 – 2.0 ltr	16.1	km/L	*Diesel*
	> 2.0 ltr	11.8	km/L	*Diesel*
	average	15.3	km/L	*Diesel*
	average	10.6	km/L	*LPG*
Minivan max.		10.9	km/L	*Gasoline*
9 persons		14.6	km/L	*Diesel*
		9.3	km/L	*LPG*
Hybrid	Middle class car	22.2	km/L	*Gasoline*
	High class car	12.4	km/L	*Gasoline*

Source: (SKAO, 2012)

4.4.5 Own transport

The data shown in Table 26 is only applicable for companies that own the mentioned transport vehicles by themselves. Also for this subject it is more desirable/accurate to track the liters of fuel consumed than to use the data showed below.

Table 26: Transport

Type		**First order energy values**		**Fuel type**
Van		5.3	tonkm/L	*Diesel*
Truck	3,5 – 10 ton	6.9	tonkm/L	*Diesel*
	10 – 20 ton	11.1	tonkm/L	*Diesel*
	> 20 ton	25.1	tonkm/L	*Diesel*
Truck-trailer		33,2	tonkm/L	*Diesel*
Train	electricity	15.5	tonkm/kWh	*Electricity*
	diesel	74.4	tonkm/L	*Diesel*
Inland shipping	32 TEU	48.3	tonkm/L	*Heavy fuel oil*
	96 TEU	42.1	tonkm/L	*Heavy fuel oil*
	200 TEU	51.0	tonkm/L	*Heavy fuel oil*
	470 TEU	59.3	tonkm/L	*Heavy fuel oil*
	Unknown	*50.2*	*tonkm/L*	*Heavy fuel oil*
Sea shipping	150 TEU	38.6	tonkm/L	*Heavy fuel oil*
	580 TEU	122.9	tonkm/L	*Heavy fuel oil*
	4000 TEU	153.9	tonkm/L	*Heavy fuel oil*
	Unknown	*105.1*	*tonkm/L*	*Heavy fuel oil*

Source: (STREAM, 2008)

4.4.6 External transport (freight)

Most service sector companies do not ship large quantities of goods across the world. It is more likely that they send correspondence or transport small shipments in packets. The widely used transport fuels are diesel (trucks), kerosene (planes) and heavy fuel oil (ships). The first order carbon values and first order energy values (Table 15) of these fuels are in a small range of each other. As it is expected that trucks (diesel) play a larger part in transport activities of small shipments and the first order carbon intensity of diesel is between the intensity of kerosene and heavy fuel oil; the chosen fuel type is diesel.

Table 27: Freight

Type	First order energy intensity		Fuel type
Packets/post up to 2 kg			
Mail NL	259.0	pieces/L	*Diesel*
Packages NL	10.3	pieces/L	*Diesel*
Mail EU	121.3	pieces/L	*Diesel*
Packages EU	8.1	pieces/L	*Diesel*
Mail/packages OEU*	5.8	pieces/L	*Diesel*
Packets per kg			
Packages NL	5.1	Pieces of 1 kg/L	*Diesel*
Packages EU	4.0	Pieces of 1 kg/L	*Diesel*
Mail/packages OEU	2.9	Pieces of 1 kg/L	*Diesel*

* OEU = Outside the EU

Source: (PostNL, 2012) *(recalculation of carbon emissions into first order energy intensity)*

4.4.7 Refrigirants

For refrigerants only the CO_2 emission factor is relevant as it has no useful energy potential. The most commonly used refrigerants are listed in the table below.

Table 28: Refrigerants

Type	First order CO_2 emission factor	
R22	1,810	g/kg
R404a	3,920	g/kg
R507	3,985	g/kg
R407c	1,775	g/kg
R410a	2,090	g/kg
R134a	1,430	g/kg

Source: (SKAO, 2012)

4.4.8 Other

Table 29: Other fuels

	First order CO2 emission factor[1]		ERE_{CO2} [2]	First order energy intensity[3]		ERE[4]
Liquid primary fuels						
Crude oil	3,130	g CO2/kg	19.3%	42.7	MJ/kg	12.0%
Orimulsion	2,219	g CO2/kg	17.6%	27.5	MJ/kg	12.0%
Natural gas condensate	2,776	g CO2/kg	22.5%	44.0	MJ/kg	12.0%
Secondary liquid fossil fuels						
Petroleum	3,099	g CO2/kg	19.7%	43.1	MJ/kg	12.0%
Shale-oil	2,639	g CO2/kg	19.4%	36.0	MJ/kg	12.0%
Ethane	2,784	g CO2/kg	23.0%	45.2	MJ/kg	12.0%
Naphthas	3,225	g CO2/kg	19.4%	44.0	MJ/kg	12.0%
Bitumen	3,381	g CO2/kg	17.6%	41.9	MJ/kg	12.0%
Lubricating oils	3,035	g CO2/kg	19.3%	41.4	MJ/kg	12.0%
Petroleum coke	3,548	g CO2/kg	14.1%	35.2	MJ/kg	12.0%
Refinery materials	3,284	g CO2/kg	19.4%	44.8	MJ/kg	12.0%
Refinery gas	3,015	g CO2/kg	21.2%	45.2	MJ/kg	12.0%
Chemical waste gas	3,015	g CO2/kg	21.2%	45.2	MJ/kg	12.0%
Other oils	2,947	g CO2/kg	19.3%	40.2	MJ/kg	12.0%
Primary solid fossil fuels						
Anthracite	2,615	g CO2/kg	4.0%	26.6	MJ/kg	7.0%
cokescoal	2,698	g CO2/kg	4.2%	28.7	MJ/kg	7.0%
Cokescoal (coke furnaces	2,738	g CO2/kg	4.1%	28.7	MJ/kg	7.0%
Cokescoal (base metal)	2,577	g CO2/kg	4.4%	28.7	MJ/kg	7.0%
(Other bituminous) Coal	2,320	g CO2/kg	4.3%	24.5	MJ/kg	7.0%
Sub-bituminous coal	1,989	g CO2/kg	4.1%	20.7	MJ/kg	7.0%
Lignite	2,024	g CO2/kg	4.0%	20.0	MJ/kg	7.0%
Bituminous shale	1,003	g CO2/kg	3.7%	9.4	MJ/kg	7.0%
Peat	1,145	g CO2/kg	3.9%	10.8	MJ/kg	7.0%
Secondary solid fossil fuels						
Coal and lignite briquettes	2,223	g CO2/kg	4.1%	23.5	MJ/kg	7.0%
Gaseous fuels						
Methane	1,971	g CO2/m^3	1.5%	35.9	MJ/m^3	3.0%

Source: 1. (IPCC, 1996)*, 2. Elaborated in* ERE_{CO2} *values other (next section),*
3. (AgentschapNL, 2011)*, 4.* (Blok, K., 2007)

ERE$_{CO2}$ values other

The ERE values are derived from comparing the first order CO_2 emission factors from the IPCC with the second order CO_2 emission factors provided by SKAO. The difference between the second order CO_2 emission factors and the first order emission factors is the ERE$_{CO2}$.

4.4.9 SKAO emission factors

A complete list of all CO_2 emission factors of SKAO can be found in Annex B.

4.4.10 Common energy prices

When the user has no information regarding the variable costs of certain energy use, the calculation tool uses the data shown in Figure 22 (CBS, 2012). Preferably the reporting company enters/correct this factor.

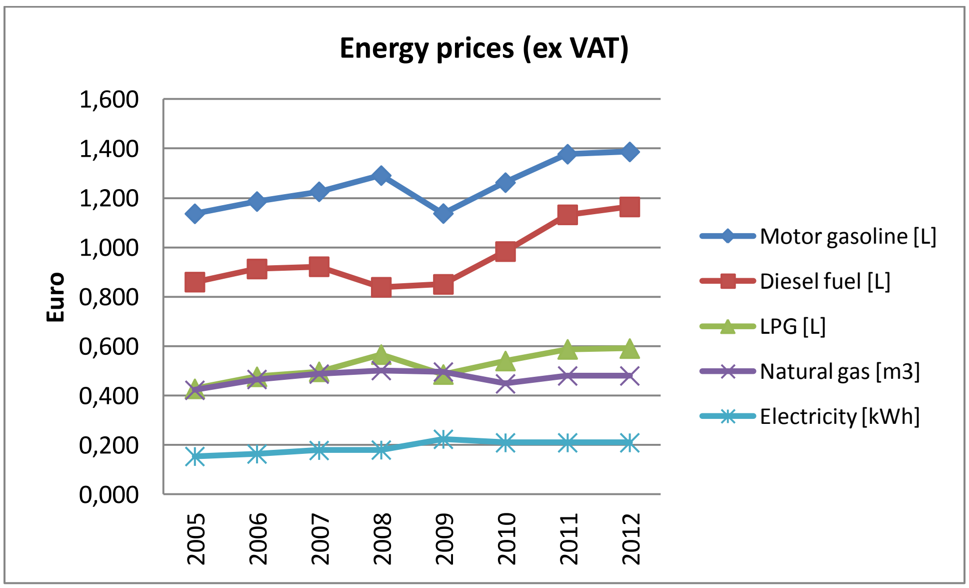


Figure 22: Energy prices 2005 – 2012

Source: (CBS, 2012)

5. Benchmark GHG assessment tool

The results of the benchmark are presented in Table 30. In the outer right column the results regarding the developed assessment tool (Energiescanner) are presented.

Table 30: Results benchmark

Data					
Name	One2Green	Fairclimatefund	Climate Neutral Group	Zeeuws klimaatfonds	Energiescanner
Country	NL	NL	NL	NL	NL
Method					
Method/Protocol	GHG Protocol and related to CO_2 prestatieladder.	For businesses	Free calculator part unknown	Unknown	GHG Protocol
Input					
Reliability activity data options	Fuel input or distance traveled	Direct emissions only fuels, indirect emissions distance travelled	Fuel input, distance traveled, efficiency	Fuel input, distance traveled	Fuel input, distance traveled, own calculation of CO_2
	(green) gas, (green) electricity, Petrol, Diesel, LPG	Just basics,	Basics and bio-fuels	Basic fuels	Extensive common fuels database
Completeness	Not complete (e.g. missing HFC emissions)	Not complete	Almost complete according GHG Protocol	Just basic subjects	Complete according to protocol
Calculation					
Transparency emission factors	No	Indirectly, emissions per subject available (recalculation possible)	Indirectly, emissions per subject available (recalculation possible)	No	Yes, justification and references available
Source	Unknown	Milieucentraal	Unknown	Unknown	Multiple external sources, IPCC, STREAM, ECN, AgentschapNL
Verifiable	No	Partly on website milieucentraal	No	No	Yes, on website and external sources
Results					
Absolute numbers	per subject and aggregate	Yes	Yes	Yes	Yes
Relative numbers	Yes (turn over, FTE)	No	Yes, turn over , FTE	No	By reporting company itself

Graphs	Yes (pie chart)	No	No	No	Yes, interactive possibilities
Monitoring	No	No	No	No	Yes, also possible per subsidiary
Other	Carbon offsetting	Carbon offsetting	Carbon offsetting	Carbon offsetting	Energy [GJ] and Variable energy costs [Euro]
Usability tool					
Manual	No	No	No	No	Yes
Cost	Free of charge	Free of charge	Free of charge	Free of charge	Unknown yet
Access	No login needed	No login needed	No login needed	No login needed	Login needed
Reporting	Against hiring	No	No	Yes, absolute numbers per subject	Yes, standard report that can be adjusted
Language	NL	NL	NL	NL	NL

The online carbon calculator of *One2Green* is easy to use but incomplete and not transparent. The organization is linked to certification schemes such as Greenkey and the CO_2 prestatieladder. The free calculator creates little confidence in their expertise. The online carbon calculator of *Fairclimatefund* is developed to get an indication of the carbon footprint of a company. Fairclimatefund uses data from Milieucentraal to calculate the carbon footprint. This data is partly verifiable but not scientifically sound. The most complete online carbon calculator in this benchmark is developed by the *Climate Neutral Group*. The design is well organized and easy to use. However, the emission factors are unverifiable and thereby not transparent. Also they do not state what method is used for the development of the carbon calculator. The last benchmarked carbon accounting tool is developed by the *Zeeuws klimaatfonds.* This tool is easy to use but only useful to get an indication of the carbon footprint. It is not complete and again not transparent on the carbon emission factors.

The benchmarked GHG assessment tools are straightforward and have not much features than calculating the total carbon footprint. The tools are however not just for indication purposes (even thou they mention it on their website), because they offer Carbon Offsetting possibilities based on the calculated carbon footprint.

6. Case study 1: Virtucon

Within this chapter Energiescanner will be tested to its full potential in the form of an assessment of the fictive company Virtucon.

6.1 Scan

The case study with a fictive dataset reveals a range in results between 126.2 ton CO_2 (Zeeuwsklimaatfonds) and 154.8 ton CO_2 (Fairclimatefund) (difference 123%). Notable is that e.g. One2Green is very clear on their website that state: "One2Green works within the strict accordance with the internationally respected Greenhouse Gas / GHG Protocol" (freely translated from Dutch) but does not make the obligatory distinction between direct and indirect emissions. Also the other used tools do not make this distinction, except for Energiescanner. It is unclear whether or not they used first order emission factors or second order emission factors. Striking is that One2green, Fairclimatefund, Climate Neutral Group and Zeeuwsklimaatfonds emphasize the possibility for direct compensation. It is in their financial interest to calculate a high carbon footprint, however only Fairclimatefund stands out comparing to Energiescanner.

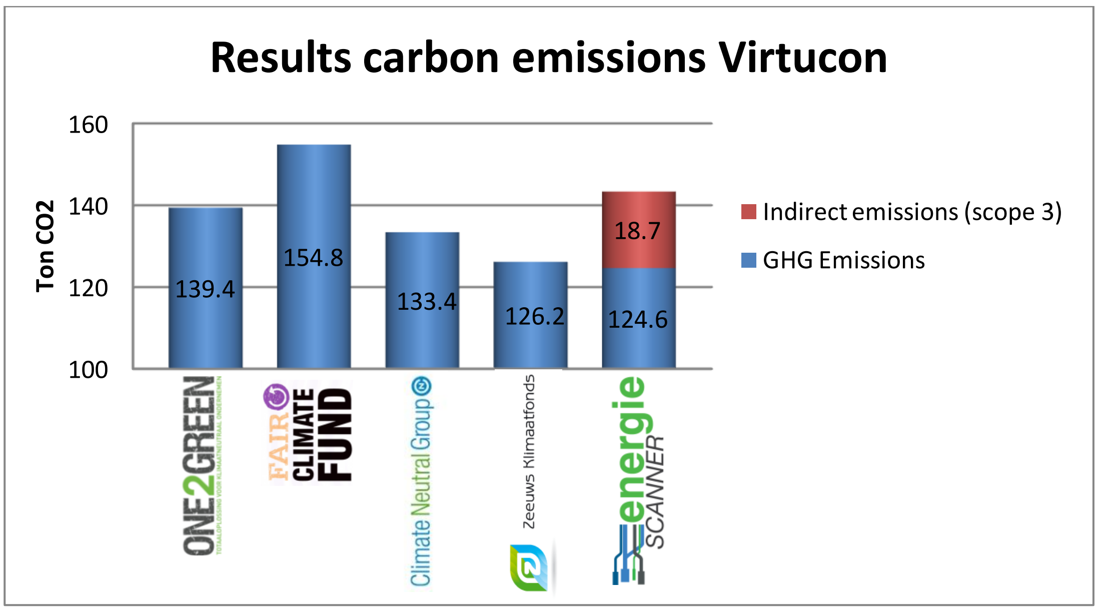


Figure 23: Results carbon footprint Virtucon

Explanation results

The first impression of the figure above is that the difference in end result of the different assessment tools is rather small. However this is more a coincidence than that the tools use the same emission factors. For example the CO_2 emission factor of electricity used by One2Green is 387 gram/kWh, while Fairclimatefund uses 550 gram/kWh, Climate Neutral Group 470 gram/kWh, Zeeuwsklimaatfonds: 630 gram/kWh and Energiescanner 559 gram/kWh. Also the CO_2 emissions of the flights differ per assessment tool. For example

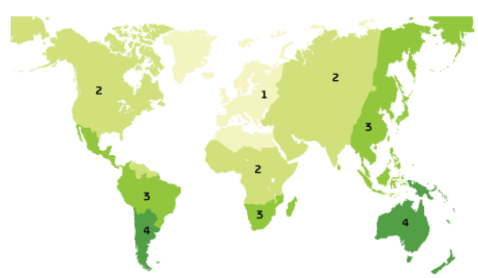


Figure 24: Regions to determine activity data

Source: (Zeeuwsklimaatfonds)

One2Green (40.2 ton), Fairclimatefund (37.8 ton) and Climate Neutral Group (37.2 ton) are almost the same, while Zeeuwsklimaatfonds allocates 23.6 ton and Energiescanner 27.2 ton CO_2. This large difference has to do with the method used by the different assessment tools to enter the activity data. Except for Energiescanner all other tools use the amount of return flights to a certain region. The tools use only four or five regions which imply a bandwidth of thousands of kilometers per region (see Figure 24).

Difference in method to enter activity data flights and impact

One2Green, Climate Neutral Group, Zeeuwsklimaatfonds uses four regions and Fairclimatefund five regions. Energiescanner uses five *categories* to calculate the total CO_2 emissions of flights. Example of allocation of 10 business trips by Virtucon employees: 10 trips of single 1,500 passenger kilometers, 8 trips of single 3,500 passenger kilometers and 2 trips of single 8,500 passenger kilometers.

Method used by benchmarked tools to enter activity data

Enter number of return trips per region:

	Region 1	Region 2	Region 3	Region 4
	10	8	2	
Single:	*0 – 3,000 km*	*3,000 – 8,000 km*	*8,000 – 12,500 km*	*12,500 - 20,000 km*

In theory the distance traveled by employees of Virtucon is between 80,000 and 238,000 km[6] (real distance is 120,000 km).

Method used by Energiescanner

Enter total distance travelled trips per category:

Category	Distance single		Number	Total distance	
0 - 1,000 km	0	pkm	-	0	pkm
1,000 - 2,000 km	1,500	pkm	10	30,000	pkm
2,000 - 5,000 km	3,500	pkm	8	56,000	pkm
5,000 - 9,000 km	8,500	pkm	2	34,000	pkm
9,000 - 20,000 km	0	pkm	-	0	pkm

The method used by Energiescanner results in much more accurate activity data, which lead to a better estimate of the GHG emissions and energy use. For the user of the tool it is easy to determine the distance between two airports as there are several free websites available which can make these calculations. The results per subjects likely determine the reduction strategy of the reporting company on which subject they want to focus on first. An accurate method to determine the activity data is therefore essential.

[6] Low: (0 km * 10 * 2) + (3,000 km * 8 * 2) + (8,000 km * 2 * 2) = 80,000 km
High: (3,000 km *10 * 2) + (8,000 km * 8 * 2) + (12,500 * 2 *2) = 238,000 km

6.2 Analyze and reduce

The projects as described in chapter 3.6 are analyzed from a financial perspective and carbon perspective related to the financial perspective in the form of a CO_2 abatement curve.

Table 31: NPV of projects

	Investment	Lifetime	Yearly savings
Project A – Replacement Airco	€ 15,000	15	€ 1,000[1]
Project B – Replacement two cars	€ 60,000	5	€ 1,173
Project C – Installation solar panels	€ 25,000	30	€ 1,800[1]

[1] based on an electricity price of 0.20 euro/kWh

CO_2 emission savings per year for different GHG assessment tools

As every GHG assessment tool uses its own emission factors the results regarding CO_2 emission savings differ. One2green is on the low end while Zeeuwsklimaatfonds is at the high end in this specific case.

Table 32: Results CO2 emission abatement per project for different GHG assessment tools

	One2green		Fairclimatefund		Climate Neutral Group		Zeeuws-klimaatfonds		Energiescanner	
Project A:	1.93	Ton CO_2	2.77	Ton CO_2	2.35	Ton CO_2	3.15	Ton CO_2	3.05	Ton CO_2
Project B:	2.68	Ton CO_2	3.04	Ton CO_2	2.67	Ton CO_2	2.73	Ton CO_2	3.24	Ton CO_2
Project C:	3.48	Ton CO_2	4.97	Ton CO_2	4.23	Ton CO_2	5.67	Ton CO_2	5.50	Ton CO_2
Carbon offsetting	*11*	*Euro/ton*	*12,50*	*Euro/ton*	*10 - 15*	*Euro/ton*	*25*	*Euro/ton*	*n/a*	

CO_2 abatement curve based on Energiescanner values

The two figures below represents CO_2 abatement cost curves. A negative value in a CO_2 abatement curve indicates that the reduction opportunity not only avoids CO_2 emissions but also saves money. The left CO_2 abatement cost curve represents an analysis of the three projects and the right curve an alternative method to reduce the carbon footprint, namely carbon offsetting (further explained in next section).

Reduction projects *OR* *Carbon offsetting*

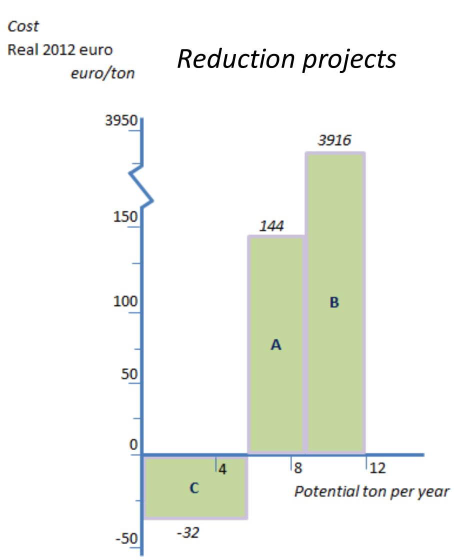


Figure 26: CO2 abatement curve projects

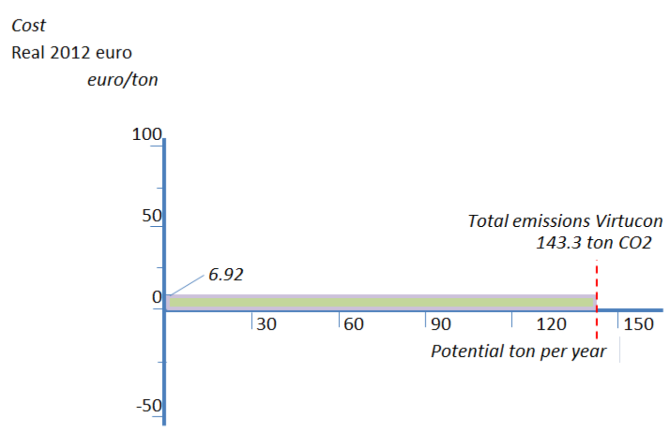


Figure 25: CO2 abatement curve carbon offsetting

Carbon offsetting

The Current Spot Carbon Dioxide (CO_2) Emissions EUA Price/Europe (26-4-2012) is EUR 6.92 per ton CO_2 (Bloomberg, 2012). The CO_2 abatement costs for two out of three projects are significant higher than the spot price of CO_2. All the benchmarked GHG assessment tools offer carbon offsetting on their website. The carbon offset prices per ton CO_2 ranges from 10 euro per ton to 25 euro per ton. The potential of carbon offsetting is from an organizational perspective infinite.

This price is extremely low compared to the investments (and accompanied risks) that have to be made in order to abate the same amount of CO_2. However carbon offsetting does not comply with the three steps of the trias energetica strategy: reduce energy demand (1), increase efficiency (2) and make use of renewable energy sources (3) (Novem, 1996). The total costs to make Virtucon complete *climate neutral* (based on Energiescanner values) is with the current spot price below 1,000 euro (6.92 euro/ton * 143.3 ton).

Energy perspective

Next to the carbon perspective it is also possible to analyze investment opportunities from an energy perspective. Next to the fact that energy accounting is more neutral compared to carbon accounting it may also be interesting for climate skeptics may not be interested in lowering their carbon footprint but are interested in lowering their total energy demand.

Table 33: Energy savings of projects

	Second order energy savings	
Project A – Replacement Airco	50.3	GJ/year
Project B – Replacement two cars	41.1	GJ/year
Project C – Installation solar panels	90.6	GJ/year

The same method used for the construction of the CO_2 abatement curve can be used to develop an energy abatement curve. The specific costs (euro/GJ) is respectively for project A: 9 euro/GJ, project B: 308 euro/GJ and for project C: -2 euro/GJ. From an energy perspective project B becomes even less attractive compared to the CO_2 perspective. This has to do with the difference in carbon intensity (gram CO_2/MJ) between diesel and electricity. For diesel the second order carbon intensity value is 88.3 gram/MJ and for electricity 60.7 gram CO_2/MJ. In other words; from a CO_2 perspective it is better to use 1 liter of diesel less compared to the equivalent in energy terms of electricity, while from an energy perspective this is not relevant (1 MJ second order value of diesel is equal to 1 MJ second order value of electricity).

7. Case study 2: Review by Loo van Eck

In June 2012, communication and advisory office Loo van Eck executed a carbon and energy assessment by means of the developed assessment tool (Energiescanner). It is the first time that this kind of assessment is carried out at Loo van Eck. In the first part the company will be introduced in more detail. The second part contains the review written by Loo van Eck (they accepted to write the review in English).

Introduction

The company is settled in one office building in an industrial area in the city of Ede. At the moment there are 43 employees (including senior management, trainers and staff) employed. There are 35 leased cars in the car park. These cars are used for business travel, commuting and personal use. All employees have the benefit of owning a tank card. This card can be used at every tank station in order to pay for the fuel (gasoline, diesel). The advantage of using these cards is that the fuel use is tracked by the liter. The reliability of the activity data is therefore very high. Next to the car park the company uses energy in the form of gas to heat the office building and electricity to power all equipment (computers, etc.).

Review by Loo van Eck

In may 2012 Willem asked Loo van Eck to participate in his research in the form of a case study. Willem told us he was developing a website with which we could perform an energy scan of our organization. Without help from expensive consultants. And free of charge. Naturally we wanted to cooperate in his research. As from this view both parties would benefit.

Willem sent us the hyperlink to his website, so we could start collecting relevant data. We quickly noticed two complexities in helping Willem: getting into the sustainability terminology, and creating time to explore this world in a busy period. After all collecting the data and filling in the form took us 2 hours. The results? First of all the report gave us an orderly view on our carbon emission. Secondly, and even more interesting, were the observations of the researcher. In his interpretations of our data he gave us suggestions for not only reducing our emission, but also reducing our costs. Very useful!

Willem claims on his website it can be used by none experts. We experienced it was still quite challenging to understand what he was really asking us, alpha’s as we are. Language is the expertise of Loo van Eck. The Energyscanner is a very useful tool, although many organizations don’t realize it. You just have to explain *why* and *how*. In more non expert language.

In the near future we plan to proceed to monitor our emission. We very much like to keep informed about the progresses in Willem’s research.

Loo van Eck
June, 2012 Ede

8. Evaluation GHG Protocol

Within this section the GHG Protocol is evaluated and supplemented with recommendations. At first the *website of the GHG Protocol* (only source of information about the GHG Protocol) will be evaluated followed by the available *downloads on the website*. Finally the *framework* as designed by the GHG Protocol will be evaluated.

Website GHG Protocol and available reports

When a visitor enters a website two things are essential: 1. Who is the target group of the website? and 2. What can the website offer me? (what can I expect). On both preconditions the website of the GHG Protocol fails. The target group can be found under tab: “About” → tab: “Users”. What the website offers is not described at all. The website of the GHG Protocol states “*The Greenhouse Gas Protocol (GHG Protocol) is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions.*” This is not a description of what to expect and a protocol is something different than a tool. This is also the main problem and critique towards the website of the GHG Protocol; it is neither a clear protocol nor an accounting tool. The protocol is described in multiple reports which have their own focus e.g. service sector, projects, scope 3. The problem is to get a complete overview of the protocol you have to read all documents which have a lot of overlap. The oldest publication dates from December 2002, while the protocol is still under construction. At the moment they are still deciding how to deal with certain issues. Noteworthy is that “*About GHG Protocol*” (Tab: About) and *“Background information”* (Tab: Media) contain exactly the same information. The design and content of the website looks a bit disorganized.

Figure 27: Screenshot website GHG Protocol

Source: www.ghgprotocol.org

Recommendations website GHG Protocol and available reports

The website needs a complete makeover. The preconditions of a good website need to be followed (define target group, describe expectations). By reading the available reports, the target groups are small and large companies in different sectors who want to have insight in their carbon emissions. This implies that the user is not necessarily an expert in the field of carbon accounting. This has implications for the writing style of the website and available reports. The lay-out of the website should be designed in a way that guides the visitor of the website. A first visitor must be triggered and have a good overview of what to expect. The available reports are the reason why visitors would return to the website. There are a lot of points of improvements for these reports. The reports (tab: Standards) are written by different partners and contributors, this means that the reports are written inconsistently. One advantage is that every report can be read separately, however if you need to read more reports there is too much overlap. A bookmark has to be created for clients so every user knows exactly what to read of which report. Some reports describe issues in more detail than other reports, for example how to deal with electricity.

Calculation tools on website

The available calculation tools may give the user a wrong first impression that there are already available templates for carbon accounting. On the frequent asked page it states the following: "*The calculation tools are available on the GHG Protocol website and are meant to complement the Protocol and make calculations easier, but their use is not mandatory.*" (GHG Protocol, 2012). The available calculation tools (developed in Excel) do not make the calculations easier, because they are very hard to understand. Also they cover only one subject e.g. transport or stationary combustion. This means that a potential user has to download several calculation tools in order to calculate the GHG emissions of the entire organization. This is not a desirable situation.

Recommendations *calculation tools on website*

As already mentioned the current calculations tools are unusable. A non-expert in the field of carbon accounting should be consulted in order to create a user friendly calculation tool. Potential users would really benefit from an easy-to-use calculation tool that is linked to the framework used by the GHG Protocol. This is however in direct competition with the developed website linked to this research, but still recommended.

Framework

The GHG Protocol developed a three phase system linked to seven-steps in order to manage the company's commitment to reduce GHG emissions. The phases are plan (1), develop (2) and manage (3).
The plan and develop phase should not be the task of the user, because every user has than to re-invent the wheel. Users should not be confronted with developing their own GHG inventory and search for relevant carbon emission factors, but should only be faced with three relevant steps which they can execute by themselves as non-expert. The development of three scopes is a good initiative, because it limits the chance of double counting. The problem however is the same as with economic accounting rules. There are different accepted methods in order to calculate and allocate activity data (as in IFRS there are several accepted methods to determine the value of stock). These inconsistencies lead to problems in comparing results from one company towards another company. Also the fact that they have not a complete available emission factor database makes it hard for a user to start using the GHG Protocol.

Recommendations framework

Instead of writing reports of several 100 pages it is also possible to make it interactive. Smart presentations could explain the framework much more efficiently reaching a larger audience. If they want that people really take action the GHG Protocol should refocus. The plan and develop phase should be exchanged for *Scan* (identify) and the manage phase should be split into two phases, namely *analyze* and *reduce*. The Scan phase must be accompanied with a standard database with emission factors. This will lower the entry barrier for many organizations. At this point the focus is too much on the accounting part, while the reduction part is underexposed. Analyzing the results may lead to unexpected insights in emission sources that build up the carbon footprint. This automatically leads to the next and last phase: reduction. Managing emissions is different than reducing emissions. The current focus of *setting targets, make a yearly report* etc. is something companies are trained in. They do it every day only from an economical perspective. By changing the routine, reducing can be more exciting and challenging. The GHG Protocol should provide a whole package on smart strategies that concern all employees of a company.

End note: objective GHG Protocol
The core objective of the GHG Protocol should be to remove the barrier for entrepreneurs to lower the carbon footprint of their organization. It is of course also possible for entrepreneurs to lower their energy need without information about the total carbon footprint. However this is not desirable as the effectiveness of the actions cannot be measured. The entry barrier for companies is not lowered by the GHG Protocol because non-experts have to hire a consultancy bureau in order to calculate their carbon footprint. This is not the situation that is preferable, because for most small companies it is too expensive to hire an expensive consultancy bureau.

9. Discussion

Within this section multiple subjects that are passed by in this thesis will be further elaborated and discussed. Some aspects of carbon accounting are difficult and sometimes even controversial in the scientific community. For practical reason multiple choices have to be made regarding the development of an emission factor database. Without making these practical choices it is impossible to identify and track the carbon footprint of a company.

Fossil fuel values

The first order emission factors and energy factors of fossil fuels will not lead to much discussion as they are fixed numbers and widely accepted. However the $ERE_{(CO2)}$ values are debatable as it is very hard to determine these values. The EP&T values that determines the $ERE_{(CO2)}$ values are case specific. The range in which different scientific sources estimate the $ERE_{(CO2)}$ value is relatively small and will lead not to significant different end results. Note that the $ERE_{(CO2)}$ values are assigned to a subject in scope 3 and are not obligatory to report. The renewable energy sources are a whole different story as they are largely debated in the scientific community. There are different methods developed within the scientific community that are able to calculate the carbon emissions of renewable energy sources. For wind, water and solar energy the IEA calculates a conversion efficiency of 100%. This is in conflict with the reality, as these types of renewable energy sources are not able to convert all energy into electricity. Also these windmills, hydropower plants and solar panels need to be constructed and maintained. How to deal with these kinds of issues varies among the scientific community. The range in which the first order emission factors, first order energy factors and $ERE_{(CO2)}$ values of biomass are valued, ranges from nothing to even worse than basic fossil fuels.

Electricity values

The largest bandwidth of carbon intensity factors is of grey and green electricity. This has to do with multiple available accepted methods which can be significantly different in taking energy (heat and electricity) production of power plants into account. In service sector companies the electricity use is often a large part of the total carbon footprint; calculations using a reliable carbon emission factor is essential. The CO_2 prestatieladder uses a value which is 20% lower than the value calculated in this report. Recalculating the CO_2 emission factors as presented in the obligatory *stroometiket* of the energy suppliers directly shows inconsistencies. These values therefore cannot be used as reliable values for carbon assessment tools.

Biomass

One of the most difficult subjects in this thesis is how to deal with biomass. According to statistics biomass must be treated as raw materials and has a carbon neutral balance. A well-to-wheel analysis of multiple research centers (incl. EU commission) came to the following conclusion regarding the GHG balance (from raw material to biofuels, whell-to-wheel) of biomass produced on grassland: " *The largest potential for expanding EU agricultural production for biofuels would be to increase the arable area at the expense of grazing land. However, there are very serious greenhouse gas consequences to ploughing up grassland. The change in land-use results in a reduction in the organic carbon stored in the soil.*

Although this only happens once, the effect is very large and long-lasting." And: *"Planting biofuels crops on grazing land would probably not pay off in GHG terms for decades."* Also: *"We conclude that planting anything on grazing or forest land would be, in the short and medium term, counter-productive with regards to GHG reductions."* (EUCAR & CONCAWE & JRC/IES, 2006). The European parliament published a directive for all member states "*on the promotion of the use of energy from renewable sources" (DIRECTIVE 2009/28/EC).* In this directive the following statement can be found: *(78) "It is appropriate to monitor the impact of biomass cultivation, such as through land-use changes, including displacement, the introduction of invasive alien species and other effects on biodiversity, and effects on food production and local prosperity. The Commission should consider all relevant sources of information, including the FAO hunger map. Biofuels should be promoted in a manner that encourages greater agricultural productivity and the use of degraded land."* (European Parliament, 2009)

These statements emphasis that biomass production is not by definition effective regarding reducing the global GHG emissions. The effectiveness of the pathway (well-to-wheel) of biomass should be analyzed from a social, economical, environmental and technical perspective. This thesis only focuses on the environmental perspective. The environmental perspective depends on the used accounting standards. The problem is that there are multiple accounting standards for biomass resulting in a wide range of results. This makes it very difficult to deal with.

GHG Protocol versus CO_2 prestatieladder

Within The Netherlands the CO_2 prestatieladder is expanding as one of the standards towards carbon accounting. Important to notice is that SKAO (organization behind the CO_2 prestatieladder) mention that it is based on the GHG Protocol but comparing the manual of the CO_2 prestatieladder and multiple reports of the GHG Protocol, some minor and major differences are revealed. The GHG Protocol is not always very clear and unambiguous on how to deal with certain issues and they also do not have a standard GHG emission database, this leaves space for own interpretation. The manuals of the GHG Protocol are over 100 pages and the available calculation tools are hard to read and understand, and not user friendly. The CO_2 prestatieladder is much easier to use and has a complete GHG emission factor database but can be debated heavily on certain subjects.

End note: Carbon accounting world

There are already multiple online carbon accounting tools available. Most of these tools offer the ability to offset the carbon footprint after you filled out a (not extensive) questionnaire. These offset practices are outside the scope of this research but are worthy to mention here. Instead of insight in the results they ask for your credit card number or another payment method to invest in a windmill in India or other not trustful and verifiable projects. The strength of this Energiescanner is that the focus is not on carbon offsetting but providing insight in energy use and the carbon footprint to lower the footprint of the organization without the easy way of carbon offsetting.

10. Conclusion

The last section of this report answers the main research question: *To what extent can the developed assessment tool provide reliable and consistent insight in the carbon and energy footprint of non-ETS companies?* First the objective of this research will be discussed, followed by an answer on all sub-questions, finishing with an overall answer of the main research question.

Objective: Development of an easy to use carbon and energy assessment tool

The GHG Protocol has an extensive website that contains multiple reports in which the framework and guiding principles are described. By following these regulations, the web-based assessment tool (Energiescanner) linked to this research is developed. However this does not guarantee that the developed assessment tool is easy to use. By benchmarking with other already available online tools and using the tool in practice (case studies), the tool is fine-tuned to make it as easy to use as possible.

1. and 2. What are currently relevant Dutch carbon/energy indicators and thereby carbon/energy intensities based on reliable and consistent calculation methods for direct and indirect emissions for non-ETS companies?

For determining Dutch carbon/energy factors it is important to make a distinction between first order emission/energy factors and second order emission/energy factors. The GHG Protocol prescribes: direct emissions (first order factors) of fuels must be allocated in scope 1 and the $ERE_{(CO2)}$ in scope 3. Most first order factors can be used universally but this does not apply for electricity factors as they are country dependent. Every country has its own fuel mix and needs therefore a tailored calculated first order emission/energy factor and $ERE_{(CO2)}$.

3. What type of analysis tools are needed within the assessment tool that can contribute to more insight in the carbon and energy footprint?

Just calculating the carbon emissions over time can be sometimes misleading as there are accounting methods to lower the carbon footprint without working more energy efficient (window dressing). These tricks can be in the form of carbon offsetting, the use of green electricity instead of grey electricity or outsource activities (as they are at this moment not obligatory to account for). In order to reduce the energy demand and to work more energy efficient it is important to visually (in the form of graphs) see which subjects within the organization uses the most energy and what type of substitution opportunities are available. For example the constructed accounting tool makes it possible to change employee commuting by personal car into employee commuting by public transport and directly see the difference in energy use (and thereby carbon emissions). Also the insight in variable costs related to the use of energy lowers the barrier towards investment opportunities for implementing energy efficient measures. The (expected) results can be filled in directly (hypothetical situation) in order to see the impact on the use of energy, the carbon footprint and the variable costs. Next to the analysis tools it is possible to download standard reports, which contain all relevant data regarding the carbon and energy footprint and variable costs. The availability of this data enables the reporting company to make financially substantiated calculations such as CO_2 abatement cost curves.

4. How do the results of the developed assessment tool compare to available web-based GHG assessment tools?
As the GHG Protocol is the most widely accepted standard within carbon accounting, their five guiding principles are used to benchmark the developed GHG assessment tool versus already available GHG assessment tools. These guiding principles are linked to the used method, input, calculation, results and usability of the tool.

Relevance (1): Not all already available carbon accounting tools ask all relevant activities and are smart constructed as they do not follow an accredited method. *Completeness (2)*: By following the GHG Protocol, most important and relevant subjects related to carbon emissions are covered. To be entirely complete, Energiescanner also added an "Other" subject for every scope. This feature enables the user to add the source in the tool that is not standard available in the form on which all activity data can be filled in (a description of this subject must be elaborated in the yearly report). This feature is not present in competitive carbon accounting tools. *Consistency (3)*: It is very difficult to create a consistent CO_2 emission factor database due to multiple perspectives, methods and ranges of emission factors. In order to be operational, a calculation tool needs fixed carbon factors, these factors can debatable. *Transparency (4)*: The easiest guiding principle to comply with is to be transparent. The carbon accounting tool has to provide insight in the used carbon factors and justify the used methods and values with references. Not all currently available tools provide this insight and are therefore not transparent in contrast with Energiescanner. *Accuracy (5)*: Activity data can be provided in multiple forms (e.g. liters used or distance travelled), there is however a hierarchy in accuracy. The most accurate method should be asked first. When this data is missing, the second best option must be available. Not all available tools have implemented this feature.

5. To what extent can the developed assessment tool help to develop a strategy in other to reduce GHG emissions and energy use?
The developed accounting tool provides a low entry barrier towards carbon and energy accounting for non-ETS companies. The added analysis tool and the extras in the form of insight in energy use and related variable costs make this tool unique in the market. Efforts in the form of energy efficiency measures can be directly calculated to envision improvements in the carbon footprint, energy use and avoided variable energy costs. These features help to steer companies towards GHG emission reductions. The case study of Virtucon showed multiple possibilities of the website to make more balanced choices regarding lowering the carbon footprint based on grounded financial analysis.

6. To what extent are the GHG Protocol and the website of the GHG Protocol shown useful in developing an accounting tool?
The framework of the GHG Protocol is very useful, but lacks detailed information. According to the GHG Protocol, information that is missing should be completed based on personal interpretations, keeping in mind the five guiding principles. Unfortunately the bandwidth in which these interpretations can be made in this scientific field is very large. The GHG Protocol is still under development, so it is possible that in the (near) future there is less uncertainty on how to deal with certain issues. The website of the

GHG Protocol is poor due to the lack of clarity. The GHG Protocol at this point is a protocol and not an accounting tool (as they state by themselves).

Main research question

To sum up and answer the main research question: *To what extent can the developed assessment tool provide reliable and consistent insight in the carbon and energy footprint of non-ETS companies?* Within this research, the accounting rules and guiding principles as set by the GHG Protocol are applied to develop an accounting tool (objective), which is able to provide consistent insight in the energy and carbon footprint of a company. The seven-step framework of the GHG Protocol is from a user perspective translated into three steps: *1. Scan, 2. Analyse* and *3. Reduce*. The time a company needs to invest to get insight in their carbon and energy footprint is reduced to a minimum. The *Scan* phase is designed in such way that the reporting company is encouraged to enter the most accurate and reliable activity data. The database, with emission and energy factors, that is needed to calculate the carbon and energy footprint is based on scientific literature. The methods described in scientific literature used to calculate some of the energy and emission factors are as consistent applied as possible (e.g. green/grey electricity values). The *Analyse* tools that are available on the website offer a deeper understanding in the carbon and energy footprint of the reporting company, including the ability to track the emissions over time. One of the unique features is that the reporting company also gets insight in the variable costs related to energy use. This opens possibilities to do economical analysis, such as NPV calculations and abatement cost curves. The standard reports that can be downloaded from the website can directly be published on the website of the reporting company. Insight in the carbon and energy footprint opens the possibility to go to the next and final phase: *Reduce.* Energiescanner offers information on how to implement the most effective carbon and energy reduction strategy. The implementation of the strategy remains the responsibility of the reporting company. However, the developed accounting tool is able to assist and steer this process.

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Abbreviations

EP&T	-	Extraction, Production & Transportation
ERE	-	Energy Required for Energy
ESD	-	Effort Sharing Decision
ETS	-	Emission Trading Scheme
GHG	-	Greenhouse gas
IEA	-	International Energy Agency
ISO	-	International Organization for Standardization
NPV	-	Net Present Value
SKAO	-	Stichting Klimaat-vriendelijk Aanbesteden & Ondernemen
T&D	-	Transport and Distribution
WBCSD	-	World Business Council for Sustainable Development
WRI	-	World Resources Institute

Scientific abbreviations

Energy

kJ	-	kiloJoules (10^3 J)
MJ	-	MegaJoules (10^6 J)
GJ	-	GigaJoules (10^9 J)
TJ	-	TerraJoules (10^{12} J)
kWh	-	KiloWatt hour (3,6 * 10^6 J)

Carbon

kg CO_2	-	kilogram CO_2 (10^3 g CO_2)
Ton CO_2	-	Ton CO_2 (10^6 g CO_2)
kTon CO_2	-	kiloTon CO_2 (10^9 g CO_2)
MTon CO_2	-	MegaTon CO_2 (10^{12} g CO_2)

Annex

Annex A – Overview subjects per scope

	Scope 1 - Direct emissions
1.1	Combustion of fuel in boilers, furnaces, or generators that are owned or controlled by the reporting company
1.2	Generation of electricity, steam, or heat in equipment that are owned or controlled by the reporting company
1.3	Business travel in vehicles such as company cars or corporate jets that are owned or controlled by the rep c.
1.4	Employee commuting in company-owned or -controlled vehicles such as company cars
1.5	HFC emissions from company-owned or -controlled refrigeration or air- conditioning equipment
1.6	Other

	Scope 2 - Indirect emissions
2.1	Consumption of purchased electricity
2.2	Consumption of purchased Steam/heat
2.3	Other

	Scope 3 - Indirect emissions (Upstream)
3.1	Business travel in non-company-owned or -controlled vehicles such as rental cars, employee cars, trains, and commercial planes
3.2	Employee commuting in vehicles not owned or controlled such as rental cars, employee cars, trains and commercial planes
3.3	Fuel- and energy related activities (not included in scope 1 or scope 2)
3.4	Upstream transportation and distribution
3.5	Other upstream activities

	Scope 3 - Indirect emissions (Downstream)
3.6	Downstream transportation and distribution
3.7	Other downstream activities

Annex B – SKAO CO_2 emission factor list

			Eenheid	2011 waarden in kg CO_2 equivalent	
1	*Personenvervoer*			WTW	
A	**Vliegtuig**				
	< 700 km	1	reizigerskm	270	g CO_2
	700-2.500 km	1	reizigerskm	200	g CO_2
	> 2.500 km	1	reizigerskm	135	g CO_2
B	**Personenvervoer met personenauto**		WTT		
	Benzine	1	liter	2.780	g CO_2
	Diesel	1	liter	3.135	g CO_2
	LPG	1	liter	1.860	g CO_2
	Aardgas	1	Nm^3	1.825	g CO_2
	Bio-ethanol (onbekende herkomst) *	1	liter	1.600	g CO_2
	Bio-gas [stortgas]*	1	Nm^3	400	g CO_2
	Bio-gas [co-vergisting maïs-mest] *	1	Nm^3	1.300	g CO_2
C	**Motorklasse auto's**	Klasse			
	Benzine	< 1,4 l	km	185	g CO_2
		1,4-2,0 l	km	220	g CO_2
		> 2,0 l	km	305	g CO_2
		Gemiddeld	km	215	g CO_2
	Diesel	< 1,7 l	km	155	g CO_2
		1,7-2,0 l	km	195	g CO_2
		> 2,0 l	km	265	g CO_2
		Gemiddeld	km	205	g CO_2
	LPG	Gemiddeld	km	175	g CO_2
D	Minibus max. 9 personen	Benzine	km	255	g CO_2
		Diesel	km	215	g CO_2
		LPG	km	200	g CO_2
E	Brandstoftype niet bekend		km	210	g CO_2
F	Middenklasse hybride (Toyota Prius)		km	125	g CO_2
	Hogere klasse hybride (Lexus GS450h/RX400h)		km	225	g CO_2
Inclusief omrijden, leegrijden, inclusief v/n transport					
	Personenvervoer collectief*****				
	Touringcar	1	reizigerskm	45	g CO_2
	Streekbus	1	reizigerskm	95	g CO_2
	Stadsbus	1	reizigerskm	120	g CO_2
	Metro/tram	1	reizigerskm	100	g CO_2
	Stoptrein	1	reizigerskm	100	g CO_2
	Intercity	1	reizigerskm	55	g CO_2
	Hoge snelheidstrein	1	reizigerskm	60	g CO_2
	Trein algemeen binnenland*	1	reizigerskm	65	g CO_2
*	Combinatiereis of treintype onbekend				
2	*Goederenvervoer*			WTW	
	Goederenvervoer algemeen				
	Benzine		liter	2.780	g CO_2
	Diesel		liter	3.135	g CO_2
	LPG		liter	1.860	g CO_2
	Bio-ethanol****		liter	1.600	g CO_2
	Stookolie		liter	3.185	g CO_2
Inclusief omrijden, leegrijden, exclusief voor- en natransport					
B	**Vervoer bulkgoederen (benuttingsgraad, omrijfactor)****				
	Vrachtwagen > 20 ton (33%,0%)	Diesel	tonkm	110	g CO_2
	Vrachtwagen < 20 ton (26%,0%)	Diesel	tonkm	295	g CO_2
	Trekker met oplegger (43%,0%)	Diesel	tonkm	80	g CO_2
	Trein (50%,10%)	Elektrisch	tonkm	25	g CO_2
		Diesel	tonkm	30	g CO_2
		Combinatie	tonkm	27	g CO_2
	Binnenvaart (51%,10%)	350 ton	tonkm	70	g CO_2
		550 ton	tonkm	70	g CO_2
		1.350 ton	tonkm	60	g CO_2
		5.500 ton	tonkm	30	g CO_2
	Zeevaart (50%,10%)	1.800 ton	tonkm	75	g CO_2
		8.000 ton	tonkm	30	g CO_2
		30.000 ton	tonkm	13	g CO_2
C	**Vervoer containers/non bulkgoederen (benuttingsgraad, omrijfactor)****				
	Bestelauto (22%,0%)	Diesel	tonkm	630	g CO_2
	Vrachtwagen 3,5-10 ton (27%,0%)	Diesel	tonkm	480	g CO_2
	Vrachtwagen 10-20 ton (26%,0%)	Diesel	tonkm	300	g CO_2
	Vrachtwagen > 20 ton (27%,0%)	Diesel	tonkm	130	g CO_2
	Trekker met oplegger (28%,0%)	Diesel	tonkm	95	g CO_2
	Trein (85%†,10%)	Elektrisch	tonkm	20	g CO_2
		Diesel	tonkm	25	g CO_2
		Combinatie	tonkm	22	g CO_2
	Binnenvaart (64%†,10%)	32 TEU	tonkm	65	g CO_2
		96 TEU	tonkm	75	g CO_2
		200 TEU	tonkm	60	g CO_2
		470 TEU	tonkm	50	g CO_2
	Zeevaart (60%†,10%)	150 TEU	tonkm	85	g CO_2
		580 TEU	tonkm	45	g CO_2
		4.000 TEU	tonkm	23	g CO_2

† benutting van containerplekken uitgaande van 10 ton lading per container.

			Eenheid	2011 waarden in kg CO_2 equivalent	
3	***Elektriciteit***				
	Ingekochte elektriciteit				
	Alle leveranciers	1	kWh	455	g CO_2
	Duurzame elektriciteit				
	Wind	1	kWh	15	g CO_2
	Waterkracht	1	kWh	15	g CO_2
	Zon	1	kWh	80	g CO_2
	Biomassa	1	kWh		
4	***Overige energiedragers voor andere doeleinden dan vervoer***			**WTW**	
A	**Vloeibare brandstoffen**				
	Benzine	1	liter	2.780	g CO_2
	Diesel	1	liter	3.135	g CO_2
	LPG	1	liter	1.860	g CO_2
	Stookolie	1	liter	3.185	g CO_2
	Bio-ethanol (onbekende herkomst) *	1	liter	1.600	g CO_2
B	**Vloeibare fossiele brandstoffen.**				
	Ruwe aardolie	1	kg	3.735	g CO_2
	Orimulsion	1	kg	2.610	g CO_2
	Aardgascondensaat	1	kg	3.400	g CO_2
	Petroleum	1	kg	3.710	g CO_2
	Leisteenolie	1	kg	3.150	g CO_2
	Ethaan	1	kg	3.425	g CO_2
	Nafta's	1	kg	3.850	g CO_2
	Bitumen	1	kg	3.975	g CO_2
	Smeeroliën	1	kg	3.620	g CO_2
	Petroleumcokes	1	kg	4.050	g CO_2
	Raffinaderij grondstoffen	1	kg	3.920	g CO_2
	Raffinaderij gas	1	kg	3.655	g CO_2
	Chemisch restgas	1	kg	3.655	g CO_2
	Overige oliën	1	kg	3.515	g CO_2
			Eenheid	2011 waarden in kg CO_2 equivalent	
C	**Vaste fossiele grondstoffen**				
	Antraciet	1	kg	2.720	g CO_2
	Cokeskolen	1	kg	2.810	g CO_2
	Steenkool (overige bitumieuze)	1	kg	2.420	g CO_2
	Sub-bitumineuze kool	1	kg	2.070	g CO_2
	Bruinkool	1	kg	2.105	g CO_2
	Bitumineuze leisteen	1	kg	1.040	g CO_2
	Turf	1	kg	1.190	g CO_2
	Petroleumcokes	1	kg	4.050	g CO_2
	Steenkool- en bruinkoolbriketten	1	kg	2.315	g CO_2
D	**Gasvormige fossiele brandstoffen**				
	Aardgas	1	Nm^3	1.825	g CO_2
	Methaan	1	Nm^3	2.000	g CO_2
	Propaan	1	liter	1.530	g CO_2
	Raffinaderij gas	1	kg	3.655	g CO_2
	Chemisch restgas	1	kg	3.655	g CO_2
E	**Overige brandstoffen/energiebronnen**				
	Warmtelevering - STEG	1	GJ	11,3	kg CO_2
	Warmtelevering - kolen	1	GJ	18,5	kg CO_2
	Warmte - AVI/overig	1	GJ	20	kg CO_2
	Warmte - gasmotor WKK	1	GJ	70,3	kg CO_2
	Warmte - geothermie	1	GJ	3	kg CO_2
	Houtmot	1	m^3	44.000	g CO_2
	Bio-gas [stortgas]*	1	Nm^3	400	g CO_2
	Bio-gas [co-vergisting maïs-mest] *	1	Nm^3	1.300	g CO_2
5	***Koel- en koudemiddelen***				
	Koudemiddel - R22	1	kg	1.810	kg CO_2
	Koudemiddel - R404a	1	kg	3.920	kg CO_2
	Koudemiddel - R507	1	kg	3.985	kg CO_2
	Koudemiddel - R407c	1	kg	1.775	kg CO_2
	Koudemiddel - R410a	1	kg	2.090	kg CO_2
	Koudemiddel - R134a	1	kg	1.430	kg CO_2

WTW staat voor well-to-wheel (complete keten)

* Op basis van (CE Delft, 2010; incl. indirect land-use effects)

** Zie STREAM studie CE Delft 2008 voor meer details

Voor gebruik en toepassing van de emissiefactoren in de CO_2-prestatieladder zie daarvoor het Handboek CO_2-prestatieladder, www.skao.nl
Voor gebruik en toepassing van de emissiefactoren voor een duurzame logistiek, zie www.emissieberekenen.nl
Voor gebruik en toepassing van de emissiefactoren in de Milieubarometer, zie www.milieubarometer.nl