CHALMERS

Environmental Assessment of a Golf Course

First Step Towards Environmental Product Declarations (EPD)

Master of Science Thesis in the Master's Programme, Industrial Ecology

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Abstract

The purpose of this master's report is to address the challenges of decreasing golf courses' environmental impact and increasing their ability to communicate their environmental performance. Sustainability and the environment are hot topics in the society nowadays and that is also the case for golf in Sweden which is why this work was initiated by the Swedish Golf Federation (SGF) and two golf clubs; Forsgården Golfklubb and Kungsbacka Golfklubb.

A lifecycle assessment (LCA) is performed on three golf courses, Forsgården GK and two fictive golf courses, Best Case GK and Worst Case GK. The two fictive golf courses are created in order to cover most of the golf courses in Sweden. From the three LCA studies hotspots for the golf course management are identified. Hotspots are the resources contributing to the most significant environmental impacts. The hotspots identified are: Alkylate, Diesel, Electricity, Environmental Diesel, Fertilizer N, Fertilizer P, Green Electricity, Herbicides, Office Paper, Petrol and Sand.

A tool is created based on the hotspots identified. The tool is a web application supposed to improve the communicability of golf clubs' environmental performance but also facilitate internal environmental work on golf clubs. From the web application two documents can be derived, a short version for communication to stakeholders and a long version for the golf club's internal work.

Transport to and from the golf course is not included in the LCA studies but is briefly studied in a screening of the golfer's environmental impact. The results of the golfer's environmental impact indicate that the transportation back and forth to the golf club often caused larger environmental impacts than the actual round of golf. Restaurants and golf shops are not studied.

The results from the LCA studies pointed out that some of the resources had a large environmental impact but that they can be reduced. Golf clubs use a lot of sand and the sand is often transported long distances, by buying sand from a local supplier the transportation and the related emissions can be reduced. Also by choosing green electricity instead of regular electricity the environmental impact can be reduced.

Acknowledgements

This thesis has been carried out at the Master's programme "Industrial Ecology - for a Sustainable Society" at Chalmers University of Technology. The thesis was initiated by the Swedish Golf Federation (SGF) and two golf clubs; Forsgårdens Golfklubb and Kungsbacka Golfklubb, and we would like to thank you all for your cooperation and support. We would also like to thank CPM - The Swedish Life Cycle Center, IVL Swedish Environmental Research Institute and Akzo Nobel for your guidance and inspiration.

We would like to thank our supervisor and examiner, Ulrika Lundqvist, for her constant support and good advice. At last we also want to thank our families and friends for supporting us throughout this project with all the ups and downs.

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Sandra Hansson and IdaMaria Persson

Abbrevations and Nomenclature

Agronomists - The agronomists are part of the Swedish Golf Federation (SGF) and each of them has responsibility over a geographical region. They are also providing guidance for golf clubs.

AP - Acidification Potential

Characterization - The relative contributions of the emissions and resource consumption to each type of environmental impact. For example, all emissions of greenhouse gases may be aggregated into one indicator for global warming and all acidifying emissions into one indicator for acidification.

EP - Eutrophication Potential

EPD - Environmental Product Declaration

Fairway - The play area between tee and green with grass high (10-15 mm) and has less intensive maintenance than a green and tee.

GEO - Golf Environment Organization

GIT - The Swedish golf IT system

Green - The area of a golf course which has the shortest grass (3-5 mm) and the most intensive maintenance. The green is the grass area that is specially prepared for putting.

Green fee - The fee for playing golf, paid by the golfers.

GWP - Global Warming Potential

Hotspots - The resources contributing to the most significant environmental impacts.

Impact Category - The category the environmental impact is described in, e.g. global warming potential or acidification potential.

Intangibles - Values hard to quantify, e.g. ecosystem quality.

ISO - International Organization for Standardization

ISO 14000 - Environmental Management Standards

LCA - Lifecycle Assessment

PCR - Product Category Rules, common and harmonized calculation rules that have to be established to ensure that similar procedures are used when creating EPDs.

POP - Photochemical Oxidation Potential

Screening - A simplified LCA study. If speed or budget is more important than precision, a screening can be made using already available or estimated data in databases. For missing data provisional alternatives are used.

SGF - Svenska Golf Förbundet (Swedish Golf Federation)

SimaPro 7 - A computer application for Lifecycle Assessment (LCA).

Stakeholders - Someone that is directly or indirectly affecting or affected by the organization/ company

Tangibles - Measurable values, e.g. CO_2 emissions.

Tee - The starting place for the hole to be played with grass high (about 10 mm) and has just less intensive maintenance than a green.

Turf - The grass covering golf courses.

Table of Contents

1. Introduction

1.1 Background

Golf is one of the largest sports in Sweden (Riksidrottsförbundet, 2011) with almost half a million members and more than 480 golf clubs (SGF, 2011 A). The sport is not just one of the largest regarding the number of members, it is also the sport requiring the largest areas of land (Gange, Lindsay and Schofield, 2003). Occupying and managing large areas of land have an impact on the environment which is naturally the case for golf courses.

Besides occupying large areas of land, golf courses use pesticides, fertilizers, water for irrigation, electricity etcetera. (Salgot and Tapias, 2006). At the end of the 21st century, golf courses started to be associated with a negative environmental impact (Wheeler and Nauright, 2006). The use of chemicals on the courses made the public question possible effects on humans and the environment. “The peak of the global golf movement has coincided with the peak of the environmental awareness movement, and more people have become less tolerant of the impact that courses have.” (Wheeler and Nauright, 2006). Media has played a big part in the public perception of golf’s environmental impact. On one hand media has made the public aware about the negative impacts golf courses have, for instance the pesticide use, but on the other hand big championships and tournaments broadcasted all over the world has made a perfect, flawless, green turf the point of reference, causing high expectations among golfers. These expectations put pressure on golf courses to achieve perfect turf, just like the turf seen in media, but sustaining such turf often needs chemicals, which have a negative environmental impact. The famous golf courses have other prerequisites than the average golf courses. One of these famous golf courses is the Augusta National in the United States. The course is held in abeyance for up to four months after a championship or tournament, repairing and treating the damage which is often the case for this kind of courses (Wheeler and Nauright, 2006). There is a wide range of different types of golf courses, all the way from the average golf course to golf courses such as the Augusta National. Common for all these golf courses are the expectations, which generally are very high and often unrealistically high.

There is an increasing awareness of problems connected to pesticide use in Sweden. There are regulations regarding the pesticide use, for example golf courses located in primary water protection zones are not allowed to use pesticides at all in compliance with the Swedish Environmental Protection Agency (14 § SNFS 1997:2). According to the 11§ (SNFS 1997:2), all sports facilities in Sweden are obliged to report anticipated pesticide use to the municipality. Sweden is not the only country taking actions against pesticide use, the Danish government has decided on phasing out pesticide use on golf courses completely (Dansk Golfunion, 2012). Sweden’s Environmental Protection Agency, Naturvårdsverket, wanted to investigate golf courses’ pesticide use and dissipation and ordered a juxtaposition which resulted in the report “Use and dissipation of plant protectants at golf courses” carried out by WSP Environmental (WSP Environmental, 2009). The result of this study showed that the Swedish golf clubs tends to use pesticides in accordance with the restricted amount.

Golf courses’ environmental impact is not only a governmental concern but also a concern for other stakeholders such as the Swedish Golf Federation (SFG) and golf clubs. The Swedish Golf Federation, SGF, encourages the golf courses in Sweden to decrease their environmental impact, and to change the negative public perception of golf’s environmental impact.

Environmental work has been a part of SGF’s agenda for quite some time. In 1999 SGF established an environmental diploma, “SGF:s Miljödiplom”. The diploma is handed out to golf clubs that have initiated their environmental work and an example of a criteria for receiving the diploma is to have established an environmental plan and policy for the golf club (SGF, 2011 B). Golf clubs can only receive the diploma once and their environmental plan should then be audited every year in consultation with an SGF agronomist.

In addition to the SGF environmental diploma there is an international organization, the Golf Environment Organization (GEO) that has a certification program which is the natural continuance for ambitious golf clubs. After getting certified according to the GEO a re-certification is required every third year in order to keep staying certified (GEO, n.d.).

The GEO certification and the SGF diploma both consider tangibles and intangibles. Tangibles, such as resource use and emissions are possible to quantify while the intangibles, such as ecosystem quality etcetera are harder measure. The intangibles can however be measured, for example, by counting the amount of species on the golf course. Both GEO and SGF are requiring some quantification of the tangibles and intangibles, but neither require an assessment of the tangibles environmental impacts. Additionally, both the GEO certificate and SGF diploma have some difficulties to communicate the environmental performance to stakeholders in a perspicuous and compact way.

Hence there is a need of a study that assesses the environmental impacts for the tangibles and improves the communicability and comparability of golf clubs environmental performance. An environmental product declaration (EPD) is a way of presenting life cycle assessment (LCA) results in a standardized way in order to enable approachable and comparable results that are easier to communicate to stakeholders (The International EPDsystem, 2012). An EPD can be a suitable option for presenting golf courses environmental performance for future reference and this report is the first step towards this. The Swedish Golf Federation (SGF) and two golf clubs; Forsgårdens Golfklubb and Kungsbacka Golfklubb have initiated this master’s report.

1.2 Purpose

The purpose of this master's report is to address the challenges of decreasing golf courses' environmental impact and increasing their ability to communicate their environmental performance.

1.3 Objectives

- To describe what kind of activities that are connected to golf courses and to determine what different environmental impacts they have.
- Perform three Life Cycle Assessments of three different golf courses; Forsgården GK, Best Case GK and Worst Case GK.
- To identify and distinguish the resources contributing to the most significant environmental impacts on a golf course, i.e. the hotspots.
- Create a tool to assess and improve the communicability of golf courses' environmental performance based on the identified hotspots.
- Perform a screening of the golfer's environmental impacts.

1.4 Delimitations

- The geographical boundaries are set to only include Sweden.
- Restaurants and golf shops are excluded.
- Transportation to and from the golf course is excluded.
- Waste treatment is excluded.
- The construction of golf courses and related buildings is excluded.
- The production of maintenance equipment is excluded.
- The study is not considering intangible values.
- The positive or negative effects of the terrestrial CO_2 uptake are not considered.

2. Methodology

The activities on golf courses and their impacts have been mapped and determined through three LCA studies of three different golf courses, Forsgården GK and the two fictive golf courses Best Case GK and Worst Case GK. Hotspots have been identified from the LCA studies by characterization. The impact categories have been chosen based on the impact categories in Environmental Product Declaration Standard, ISO 14025. The LCA studies have also been complemented with a screening, adding the contribution of the golfer's environmental impacts. Finally, a web application has been developed in order to simplify environmental assessment of golf courses and also facilitate communication of the results to stakeholders.

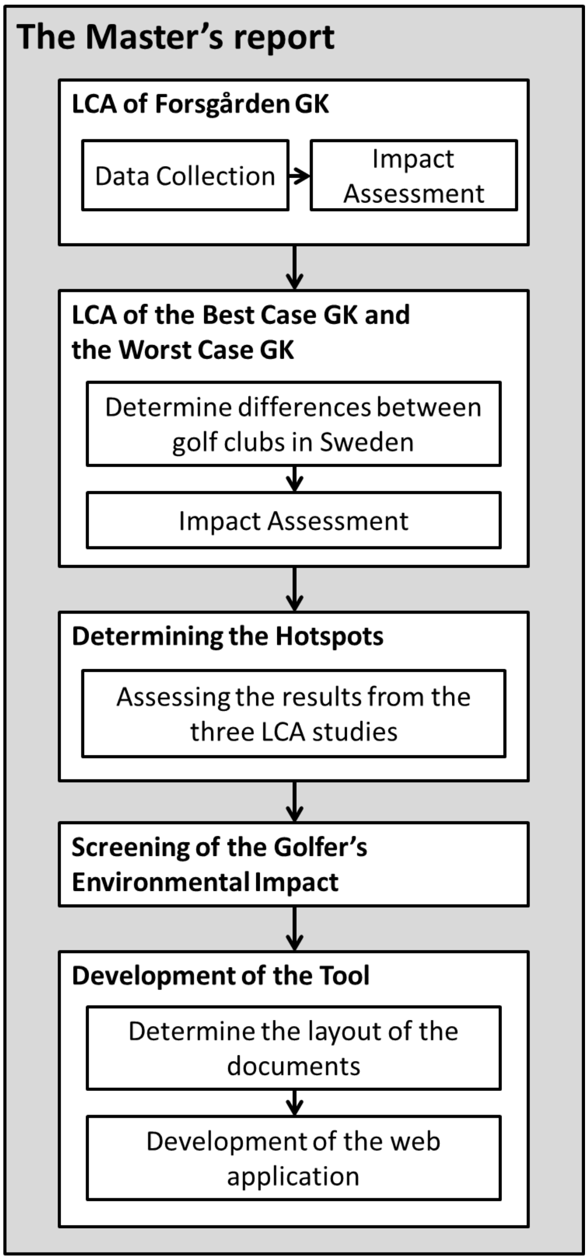


Figure 1: An overview of the work flow in this report. All parts are described subsequently.

2.1 LCA of Forsgården GK

The focus of the LCA study of Forsgården GK has been golf course management since that is the part that the golf club itself can affect. The aim of the LCA study has been to declare Forsgården's environmental impact in order to find the hotspots in golf course management. The LCA of Forsgården GK is a gate-to-gate study.

The LCA study has been carried out in the LCA software SimaPro. SimaPro has databases with data of production of resources and emissions connected to this (PRé Consultants, 2010). Characterization, normalization and weighting etcetera are automatically calculated for the resources and only the amount and the linkage between the resources are added. Some information such as emissions from combustion of fuels and leakage from fertilizers are not included and has therefore been determined and added to SimaPro. The resources used and the assumed emissions are presented in appendix V and VI.

An 18-hole round of golf has been chosen as the functional unit and the golf round has been seen as a service. The unit focuses on golf course operation and is easy for stakeholders to relate to. Also golf clubs with high utilization are encouraged since high utilization affects the results positively and high utilization is seen as having a high public welfare. Forsgården GK both has one 18-hole and one 9-hole golf course. A 9-hole round of golf is assumed to equal half an 18-hole round of golf, thus half the amount of 9-hole rounds are added to the total amount of 18-hole rounds. Most of the 18-hole rounds but no 9-hole rounds are registered in GIT (Golf's IT system), therefore the estimated number of both 18-hole and 9-hole golf rounds have been used to calculate the results per functional unit.

The system boundaries have been based on considering a golf round as a service and what should be included in the study is the same that is included in the green fee. Therefore the restaurant and the golf shop have been excluded from the LCA study since their services are not included in the green fee. The construction of the golf course and the related buildings has also been excluded from the study, since the construction is not possible to affect subsequently for the existing golf courses. The focus is instead on golf course operation which can be affected. The production of maintenance equipment has been excluded from the study since it is considered as capital goods where the emissions from the production are negligible compared to the emissions connected to the usage phase (Baumann and Tillman, 2004).

All flows connected to this LCA study are presented in several flow charts. The main flow chart of Forsgården GK has been divided into three modules; upstream activities, core module and downstream activities, where all activities inside the core module are within the system boundaries. The activities inside the core module are described further with additional flow charts.

The data collection for the resource use for all activities in the golf course operation has been made through interviews with employees, suppliers and by annual reports and data at Forsgården golf course. All data for Forsgården GK is taken from 2011's resource consumption. The database in SimaPro has been used, but with some additions, presented in appendix V-VI. No allocation has been made since the resource use for the whole system has been envisaged and has not been divided per activity.

The impact assessment describes the environmental loads in the inventory analysis and narrows down the number of parameters by aggregating the relative contributions into the chosen impact categories (Baumann and Tillman, 2004). An LCA can consist of three parts, classification, characterization and weighting. For this study only classification and characterization have been considered. Both the classification and characterization are automatically done in SimaPro, thus only the characterization is presented.

The impact categories have been chosen based on the impact categories used in EPD. Since the master's report is a first step towards EPD, the structure has been influenced by the structure of EPDs. Global Warming Potential (GWP), Photochemical Oxidation Potential (POP), Ozone Depletion Potential (ODP), Acidification Potential (AP) and Eutrophication Potential (EP) are the impact categories chosen.

2.2 LCA of Best Case GK and Worst Case GK

Additionally, two LCA studies have been performed of two fictive golf clubs; Best Case GK and Worst Case GK, in order to create a range covering most of the golf clubs in Sweden. The aim of the LCA studies is that most Swedish golf clubs end up within the range of Best Case GK and Worst Case GK so that the hotspots derived are representative for Sweden and that possible hotspots that have not been covered by the LCA of Forsgården are identified.

In order to determine differences and deviations between golf clubs in Sweden interviews with SGF agronomists have been made. The SGF agronomists are each responsible for different geographical regions of Sweden. Furthermore, several municipalities in Sweden have also been contacted to collect data for the use of pesticides on different golf courses. The golf courses were randomly selected and were all located in different geographical regions. Forsgården GK has been the starting-point for Best Case GK and Worst Case GK, however the assumptions have, besides the interviews with the SGF agronomists, also been based on interviews with other people well conversant in the respective area. Assumptions made on patterns of usage and periodicity of replacing parts and materials are derived from these interviews. Additionally, a literature review has been performed in order to broaden the view of golf course management. Results from other LCA studies have also been used.

In order to make all three LCA studies performed in this report comparable, the same base assumptions have been made and are performed similarly. It has been assumed that all have the same amount of 18-hole rounds and the same system boundaries apply. The results are presented in the same way as for Forsgården GK with the exception that no redundant information is presented, only the differences.

2.3 Determining the Hotspots

The hotspots of golf course management have been determined based on the results of the characterization of the three LCA studies, Forsgården GK, Best Case GK and Worst Case GK. All resources are categorized as definitive, possible or no hotspots. The final hotspots consist of all the definitive hotspots plus the possible hotspots that have been analyzed and determined to be final hotspots.

To determine if a resource is a definitive, possible or no hotspot, the relative contributions of the resources for each impact category have been assessed. One impact category at a time has been studied and resources contributing with more than 1% have been marked with an "X" in the table (Table 1). The limit has been set to 1% in order to get high coverage and include the resources with the most significant impacts. Resources with two or three "X:es" are definitive hotspots even if they have just been considered as definitive hotspots in one of the impact categories. Resources with no "X:es" at all in all of the impact categories are considered to be no hotspots, while resources with one "X" in one or more of the impact categories are considered to be possible hotspots.

Impact category	Resources	Forsgården GK	Best case GK	Worst case GK	Hotspots
	Diesel	x	x	x	Definitive hotspot
	Petrol	x		x	Definitive hotspot
	Fertilizer		x		Possible hotspot
	Water				No hotspot

Table 1: Example table of how the hotspots are determined. The resources are just examples and not a result.

If a possible hotspot has only been over the 1% limit for Best Case GK the possible hotspot is not considered a hotspot. Since no fossil fuels consumption occur at Best Case GK many resources with small environmental impacts exceed the 1% limit, which is not likely in a near future, therefore these resources are considered a no hotspots.

2.4 Screening of the Golfer's Environmental Impact

Even though the focus of this report has been on golf course management, the impact of the golfer has also been assessed briefly in the form of a screening. A screening is a type of LCA study where rough values can be used to get an overview of the impact of a product or service (PRé Consultants, 2010). The aim of the screening is to obtaining a holistic perspective as well as for further studies in the subject.

The system boundaries for the screening of the golfers environmental impact is, in contrast to the LCA studies, everything that the golfer needs in order to play a round of golf. That includes transportation to and from the golf club and use of equipment such as golf clubs, gloves etcetera. The equipment has been mapped and periodicity of replacing equipment has been analyzed in order to find the hotspots in the golfer's environmental impact. Food is however not included, since it is not a necessity for a round of golf.

2.5 Development of the Tool

A tool for assessing the environmental performance of golf clubs in Sweden has been developed in order to give golf clubs a way to communicate their performance to stakeholders. The web application includes and assesses the impact of the resources that has been identified as hotspots.

The most important part of the development of the tool is to decide how to communicate the results to golf clubs and other stakeholders. Therefore the content and layout have been decided on in an early stage and evaluated with all involved parties.

The web application has been developed in Visual Studio 2010 (Microsoft Visual Studio, 2012) using ASP.NET and C# (w3schools.com, 2012). To present the bar charts jqPlot have been used (jqPlot, 2012). The database used is Microsoft Office Access (Microsoft Office, 2012) and has been used to store information about the clubs, environmental impact data and results (Microsoft Office, 2012).

The requirements for the web application are presented below. A document with the environmental impacts is called *environmental impact profile* in the list. The web application has the following requirements represented in the form of user stories:

- As a user I want to be able to log in to the application
- As a user I want to see a list of my saved environmental impact profiles
- As a user I want to see and be able to change my user information and information about the golf club
- As a user I want to be able to enter the resources for a new environmental impact profile
- As a user I want to be able to change the resource use of an existing environmental impact profile
- As a user I want to be able to view the environmental impact profiles in a short version for communication to stakeholders and long version for golf clubs internal environmental work
- As a user I want to be able to delete an existing environmental impact profile
- As a user I want to enter the resources with a unit that I prefer
- As a user I want to have feedback when entering resource use on what to enter
- As a user I want to print the long and short EPD and get feedback on how to disable the printer headers and footer.

- As an unauthenticated user I want to get information about the application on the login page

The result of the application has been compared with the result from the three LCA studies in order to ensure a high enough accuracy in the magnitude of the environmental impacts. Some user tests have also been performed to evaluate the user experience and improve the usability.

3. Results of Forsgården LCA

3.1 Results of the Inventory Analysis of Forsgården GK

Forsgården GK is a golf club located in Kungsbacka, Sweden, and had in 2011 approximately 1 500 members. There is one 18-hole and one 9-hole golf course. Forsgården GK is occupying a total of 95 ha where the golf courses, infrastructure, club houses, the surrounding vegetation, etcetera are included. The total amount of greens is estimated to 2.2 ha and 19 ha is fairway.

The total amount of registered 18-hole golf rounds for the year 2011 in GIT (the Golf's IT-system) is 24 596, but not all rounds are registered. Forsgården GK has estimated that the total number of 18-hole golf rounds is 35 000 rounds for 2011. The 9-hole rounds are not registered at all but are estimated to 10 000 rounds. Hence the amount of golf rounds used to calculate the functional unit is 40 000 for the year 2011, the estimated amount of 18-hole rounds plus half the estimated amount of 9-hole rounds.

The system is divided into three modules; upstream activities, core module and downstream activities where only the core module is included in the system boundaries, see Figure 2. The core module is presented in 3.1.1 and the groups of activities within the main activities in the core module are presented in 3.1.1.1–3.1.1.4.

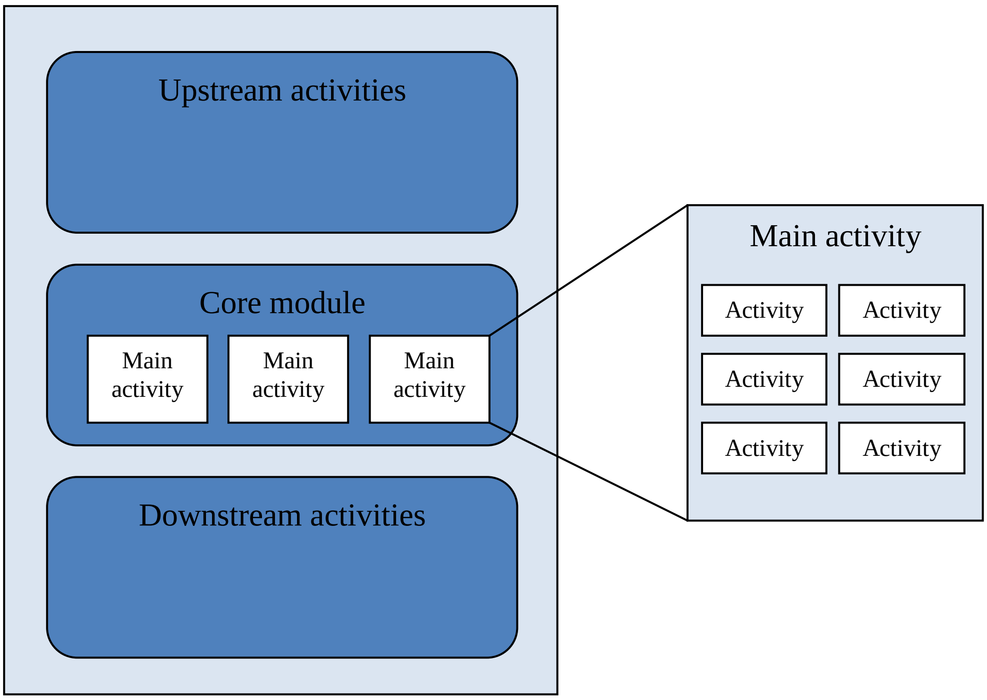


Figure 2: The core module is inside the system boundaries and the main activities in the core module each consists of many sub-activities.

3.1.1 Flow Charts

The flow chart of Forsgården GK is presented in this section, picturing the main activities in the system, see Figure 3. The activities in the core module are the activities included in the study and are inside the system boundaries. These main activities in the core module are described more thorough in section 3.1.1.1-3.1.1.4.

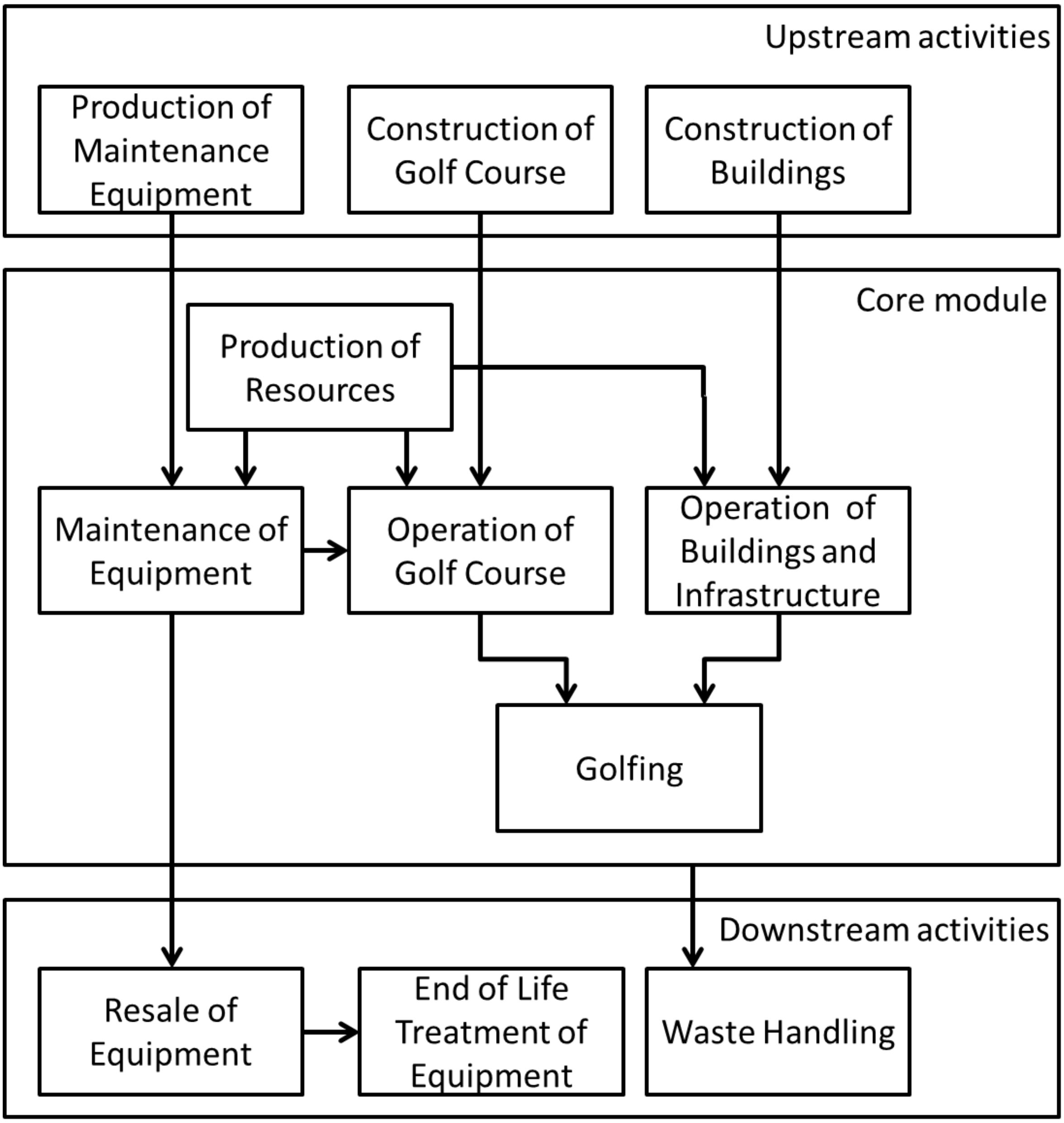


Figure 3: Upstream activities, Core Module and Downstream activities. The activities within the Core Module inside the system boundaries and are presented more thorough in the subsequent section.

3.1.1.1 Operation of Golf Course

This section describes the activities connected to "Operation of Golf Course", with related resources, at Forsgården GK are presented in Figure 4.

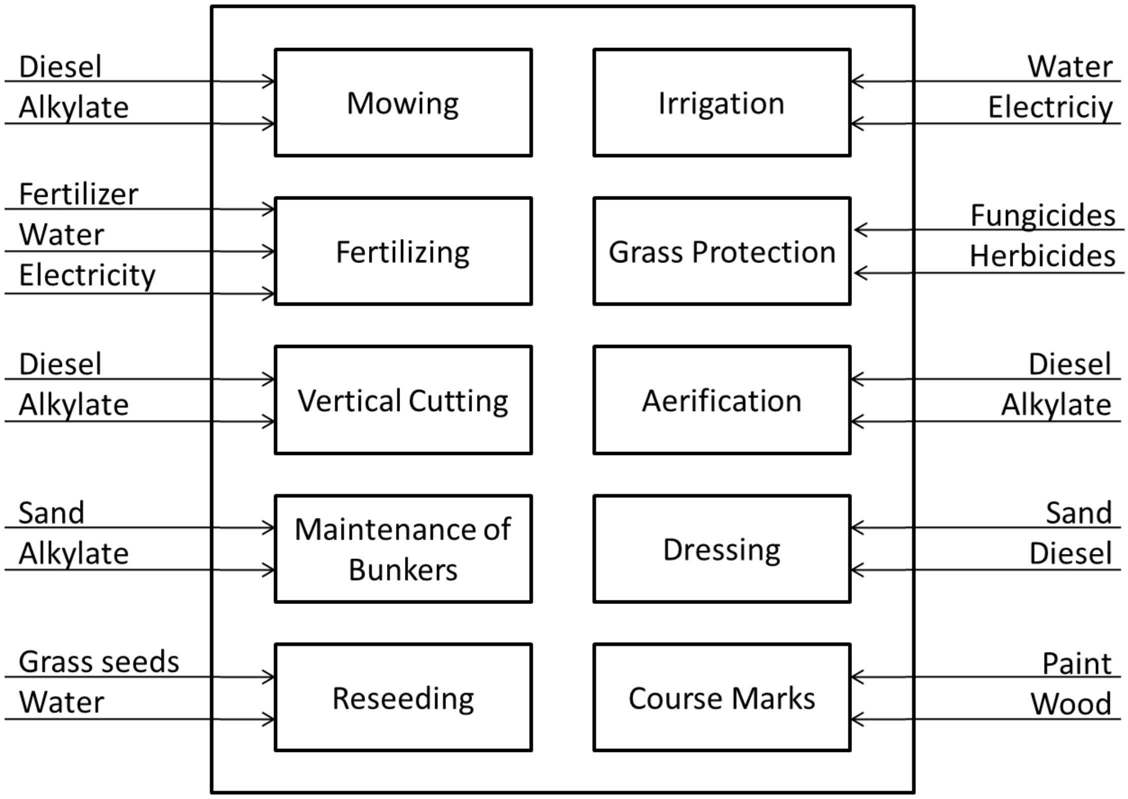


Figure 4: Flow chart of the main activity "Operation of Golf Course" and appertained activities with related resources.

The core of operation of a golf course is managing the turf; the turf needs to be mowed, fertilized, vertically cut, irrigated, protected from tares and fungus, aerificated, dressed and reseeded. The turf is differently managed, greens are managed the most intensively and ruffs are hardly managed at all. For example different mowers are used for mowing the golf course; there are mowers for the green, fairway, tee etcetera. A golf course needs a quite big machinery fleet consisting of mowers, tractors and other vehicles and machines. Forsgården GK has 32 vehicles, their entire machinery fleet is attached in Appendix III. The machinery fleet is mostly consuming environmental diesel (MK1) and alkylate.

The turf on the golf course needs to be irrigated. For Forsgården GK's case the water for irrigating the course is taken from the small river Söderå that is passing by the golf club. Electric pumps are used for the irrigation. The golf course is also drained.

Fertilizing is another activity on golf clubs. The fertilizing on Forsgården GK is based on continuous soil samples determining the ratio between the three different fertilizers;

nitrogen, phosphorus and potassium. Fertilizing is can be done in connection with the irrigation.

Fungicides and herbicides are used for turf protection. The turf is protected from tares by using herbicides when necessary. In case of a fungus attack, fungicides are used. Forsgården GK uses one kind of herbicide, Spitfire, and two kinds of fungicides, Amistar and Baycore.

The turf is also mechanically treated; it is subjected to vertical cutting, aerification and dressing. These activities are done in order to increase the access of air in the root system and decrease the thatch. A lot of sand is used for dressing. The sand used for dressing of greens is washed in contrast to the sand used for the fairways which is not. Fossil fuels are also used since all the activities are done mechanically with dressers, vertical cutters etcetera. The aerification creates a lot of organic waste, which is composted and reused for repairing the golf course.

Sand is not only used for dressing, it is also used for maintaining the bunkers. The sand is bought at Lysegården outside of Kungälv and transported to Forsgården GK, the distance is 60 km.

Due to ice injuries or other incidents the turf might die on spots and therefore grass seeds must be sown. The need of reseeding varies a lot depending on climate, drainage etcetera.

Golf courses must be marked and on Forsgården painted sticks made of wood have been used.

3.1.1.2 Maintenance of Equipment

This section describes how the equipment used on Forsgården GK is maintained. The activities connected to the "Maintenance of Equipment", with related resources, at Forsgården GK are presented in Figure 5.

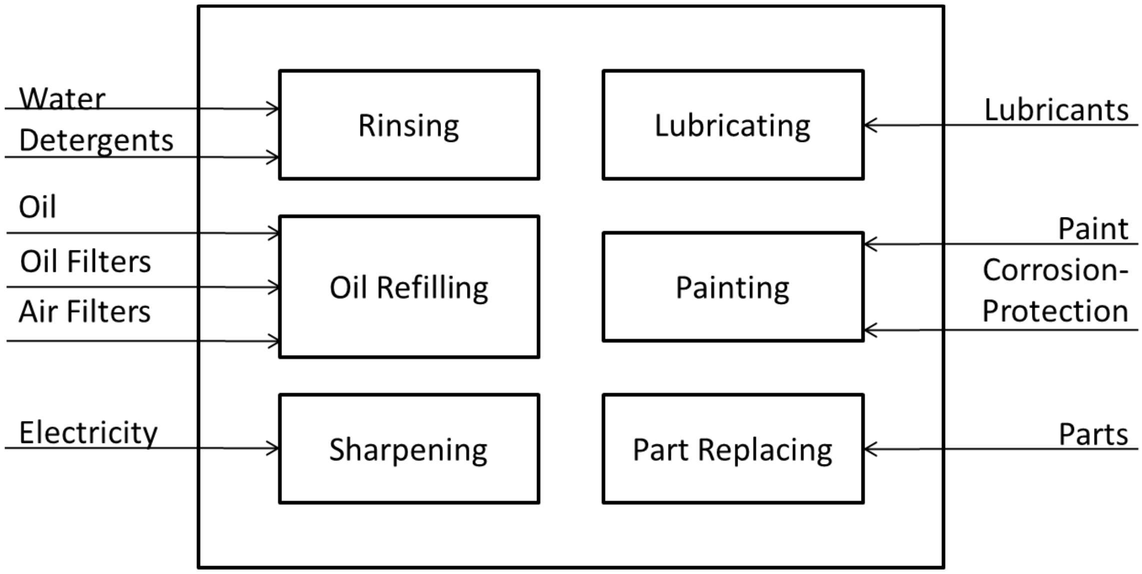


Figure 5: Flow chart of the main activity "Maintenance of Equipment" and appertained activities with related resources.

The equipment used on a golf course is used intensively and the performance of the equipment is of high importance, therefore the maintenance of the equipment is done extensively to ensure as high quality as possible. The mowers are rinsed after every use, they are rinsed with a mix of water and detergent. The detergent used on Forsgården GK is called MAC AB54. The waste water passes an oil separator before returned to the hydrologic cycle.

A lot of different vehicles and machines are used in golf course operation. In order to keep the engines in good shape they are lubricated regularly. Also oil and oil filters needs to be changed regularly in order to maintain a high performance. At Forsgården, oil and oil filters are changed once a year for all the vehicles, which is also the case for air filters. Many of the vehicles are frequently washed and exposed to a corrosive environment, therefore corrosion protection and painting is done in order to keep the vehicles in good shape.

The bedknives and knife cylinders get blunt quickly and have to be sharpened. Forsgården GK has electric equipment for sharpening of both the bedknives and the knife cylinders. The bedknives on the green mowers are sharpened after every usage and the knife cylinders only when needed. Eventually they are hackneyed and not possible to sharpen any more, then they are replaced with new parts. Other parts that are changed regularly are coring tines, solid conventional tines and roller bearings. The metal scrap that is glomerated at Forsgården, as well as the waste oil are sent to recycling, which is not considered in this study.

3.1.1.3 Operation of Buildings and Infrastructure

This section describes how the buildings and infrastructure at Forsgården GK are maintained. The activities connected to the "Operation of Buildings and Infrastructure", with related resources, at Forsgården GK are presented in Figure 6.

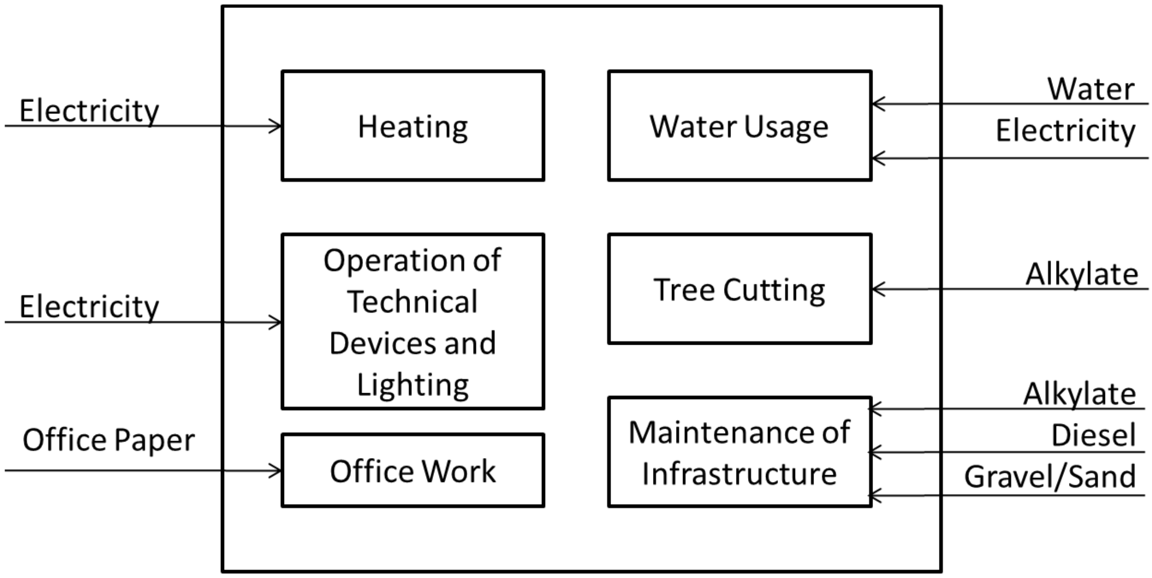


Figure 6: Flow chart of the main activity "Operation of Buildings and Infrastructure" and appertained activities with related resources.

Forsgården GK has a club house and a main building with front desk, secretariat, changing rooms etcetera. The main building is open throughout the year and therefore needs to be heated or cooled, but also needs water and electricity. The water used is from the municipal water system. The secretariat is also manned throughout the year and besides water, electricity and heating, office related material such as office paper is used.

The infrastructure on Forsgården GK is overhauled and touched up once a year. Depending on the state of the infrastructure, different kinds of measures are required. Usually sand and gravel is used to fix the roads. Sometimes bigger excavators are needed but it all depends on the state.

The golf course does not just consist of grass, there are small forests etcetera that needs to be maintained. The forest is disforested regularly. For the disforestation, chainsaws are used which runs on fossil fuels.

3.1.1.4 Golfing

This section describes the activity golfing at Forsgården GK. The activities connected to "Golfing", with related resources, are presented in Figure 7.

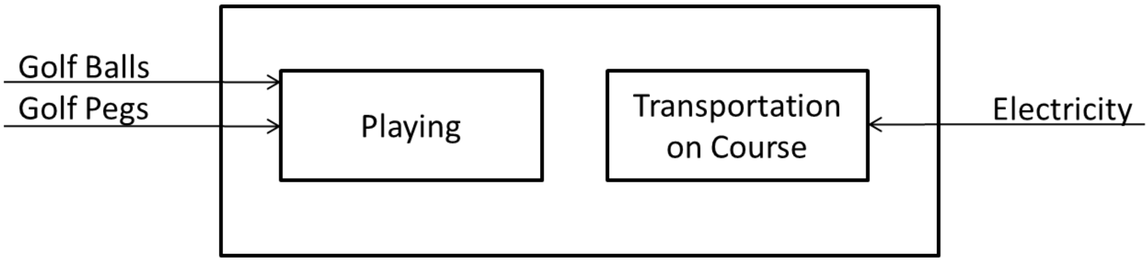


Figure 7: Flow chart of the main activity "Golfing" and appertained activities with related resources.

Only the activities that are directly affecting the golf course are included within the system boundaries. Therefore transports back and forth to the golf course are not included here, only the transportation on course is considered. The transportation can be made by renting a golf cart, but to rent golf carts can sometimes require a doctor's certificate.

Golf balls and pegs are used when playing golf, and these are at times lost and left behind on the golf course. The production of golf balls and pegs is not included in the LCA study since only activities directly affecting the golf course are considered. Lost golf balls and pegs left to decompose on the golf course are on the other hand affecting the golf course directly.

3.1.2 Resources and Related Amounts for Forsgården GK

All resources and the amount used are presented in Table 2 below. The amount of the resources used is both data given by Forsgården GK and assumptions made regarding the amount used. All assumptions regarding amount are presented in Appendix VI.
The resources at Forsgården GK corresponds to resources in SimaPro, the choices of the corresponding resources in SimaPro are presented in Appendix V. Assumptions made regarding emissions to some resources are also presented in Appendix V.

Resource	Amount	Unit
Alkylate	1 875	kg
Anti-rust Agent	32	kg
Cast Iron	333	kg
Corrugated Board	616	kg
Course Marks	1	m^3
Detergent Mix	420	kg
Enamel Paint	32	kg
Environmental Diesel	14 400	kg
Fertilizer K	770	kg
Fertilizer N	2 132	kg
Fertilizer P	230	kg
Fungicides	1.2	kg
Golf Balls	40 000	pieces
Golf Pegs	80 000	pieces
Grass Seeds	100	kg
Green Electricity	210 440	kWh
Herbicides	40	kg
Hydraulic Hoses	16	kg
Iron Sulphate	300	kg
Lubricant Oil	8	l
Motor Oil	142	kg
Office Paper	1 078	kg
Oil and Air Filters	5	kg
Sand	1 300	ton
Tires	32	pieces
Water, Dam	35 000	m^3
Water, Municipality	764.5	m^3
Wood Paint	2	kg

Table 2: The amount of the different resources used on Forsgården GK.

3.2 Results of the Impact Assessment of Forsgården GK

The characterization for Forsgården GK is presented in this section.

3.2.1 Characterisation

All the resources' environmental impacts have been characterized and are presented below for all assessed impact categories. The figures are presented in percentage. A limit is set at 1%, resources contributing to 1% or more of the environmental impacts can be hotspots and are therefore of interest. The total amount of impact equivalents (eq) can be found in Appendix I.

3.2.1.1 Global Warming Potential

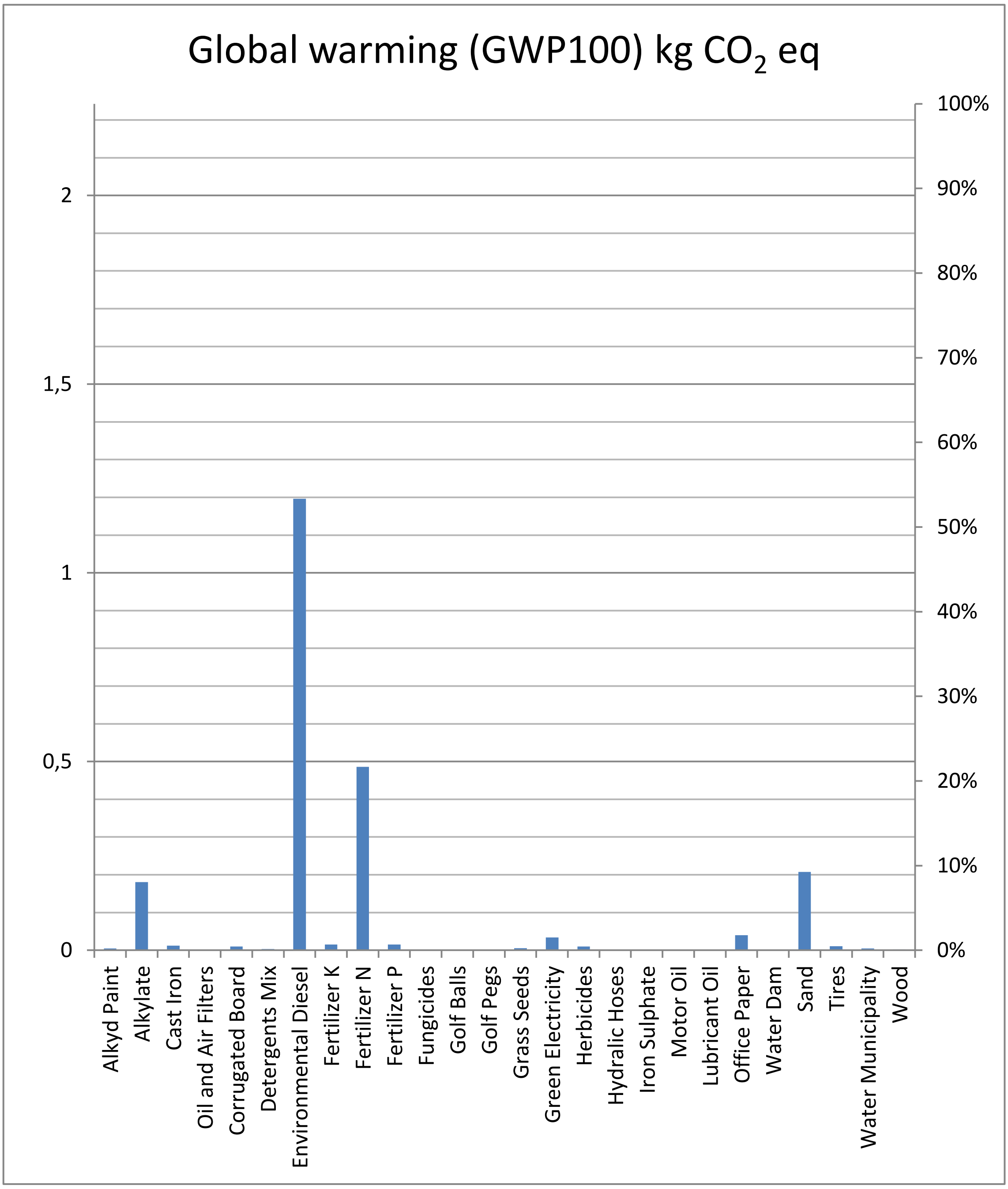


Figure 8: The global warming potential for Forsgården GK presented in percentage. All data for each resource can be found in appendix I

One 18-hole round at Forsgården GK contributes to the global warming potential with 2.24 kg CO_2 equivalents. The resource that has the most significant impact is environmental diesel (MK1) with 1.2 kg CO_2 or 53% of the total global warming potential for Forsgården GK. Fertilizer N has the second largest impact with 0.49 kg CO_2 or 21%. Resources which have more than 1% of the total global warming potential are alkylate, electricity, office paper and sand.

3.2.1.2 Acidification Potential

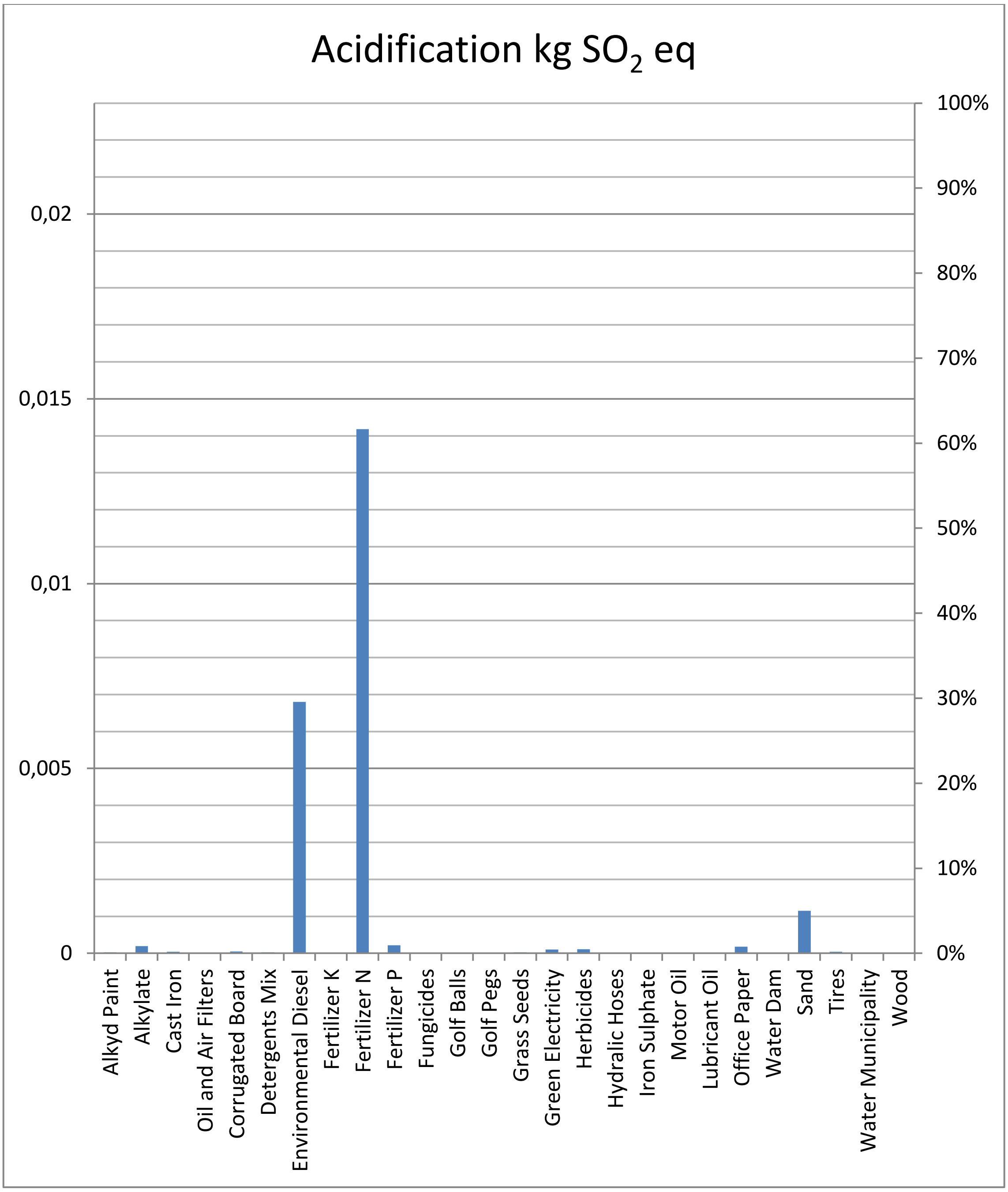


Figure 9: The acidification potential for Forsgården GK presented in percentage.

One 18-hole round at Forsgården GK contributes to the acidification with 0.023 kg SO_2 equivalents. The biggest contributor to acidification on Forsgården GK is fertilizer N with 0.014 kg SO_2 equivalents and represents 61% of the total acidification potential for Forsgården GK. Environmental diesel (MK1) has a potential of 0.0068 kg SO_2 or represents 29%. Sand is also above the 1% limit.

3.2.1.3 Eutrophication Potential

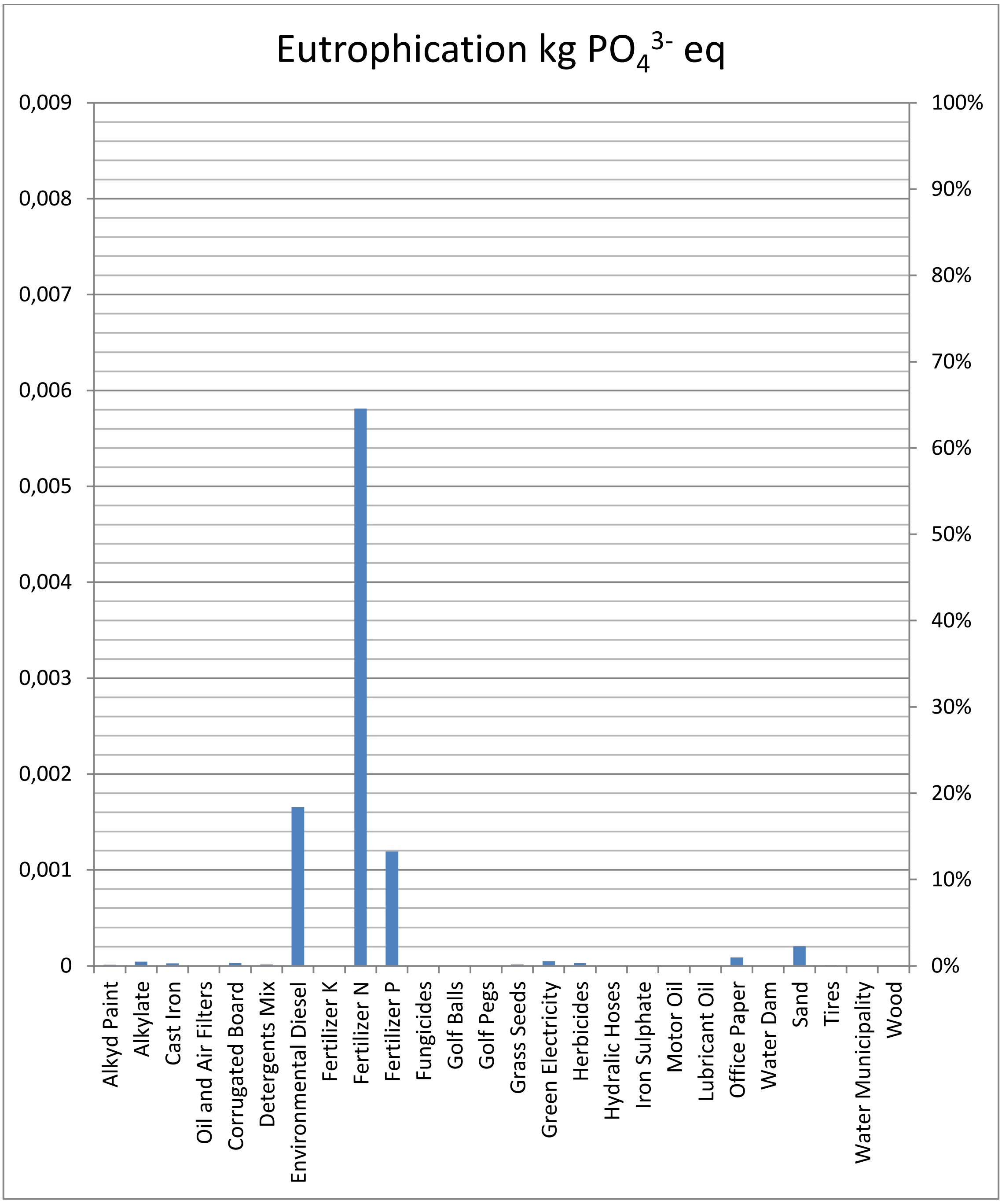


Figure 10: The eutrophication potential for Forsgården GK presented in percentage.

One 18-hole round at Forsgården GK contributes to the eutrophication with 0.0091 PO_4^{3-} equivalents. For eutrophication the biggest contributor is fertilizer N with 0.0058 kg PO_4^{3-} representing 63%. But also fertilizer P contributes with another 0.0012 kg PO_4^{3-} representing 13%. These two resources are the most significant contributors. Environmental diesel and sand are also above the 1% limit.

3.2.1.4 Photochemical Oxidation Potential

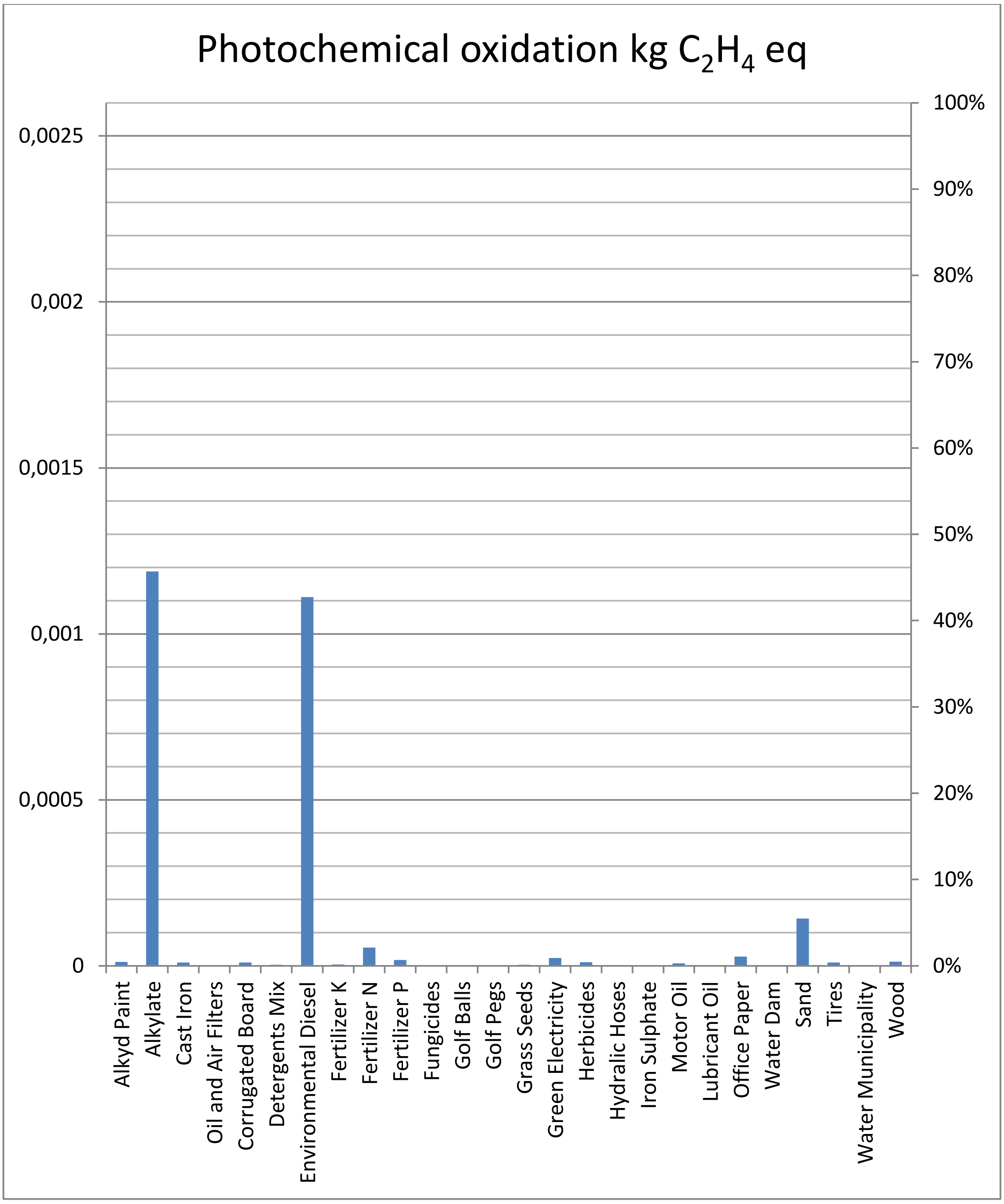


Figure 11: The photochemical oxidation potential for Forsgården.

One 18-hole round at Forsgården GK contributes to the photochemical oxidation with 0.0027 kg C_2H_4 equivalents. Alkylate and environmental diesel are more than four times larger contributor to photochemical oxidation than the next largest contributor. Alkylate have 0.0012kg C_2H_4 equivalents with 43% and environmental diesel 0.0011kg C_2H_4 eq and 42%. Sand, fertilizer N, office paper and electricity are also over the 1% limit.

3.2.1.5 Ozone Depletion Potential

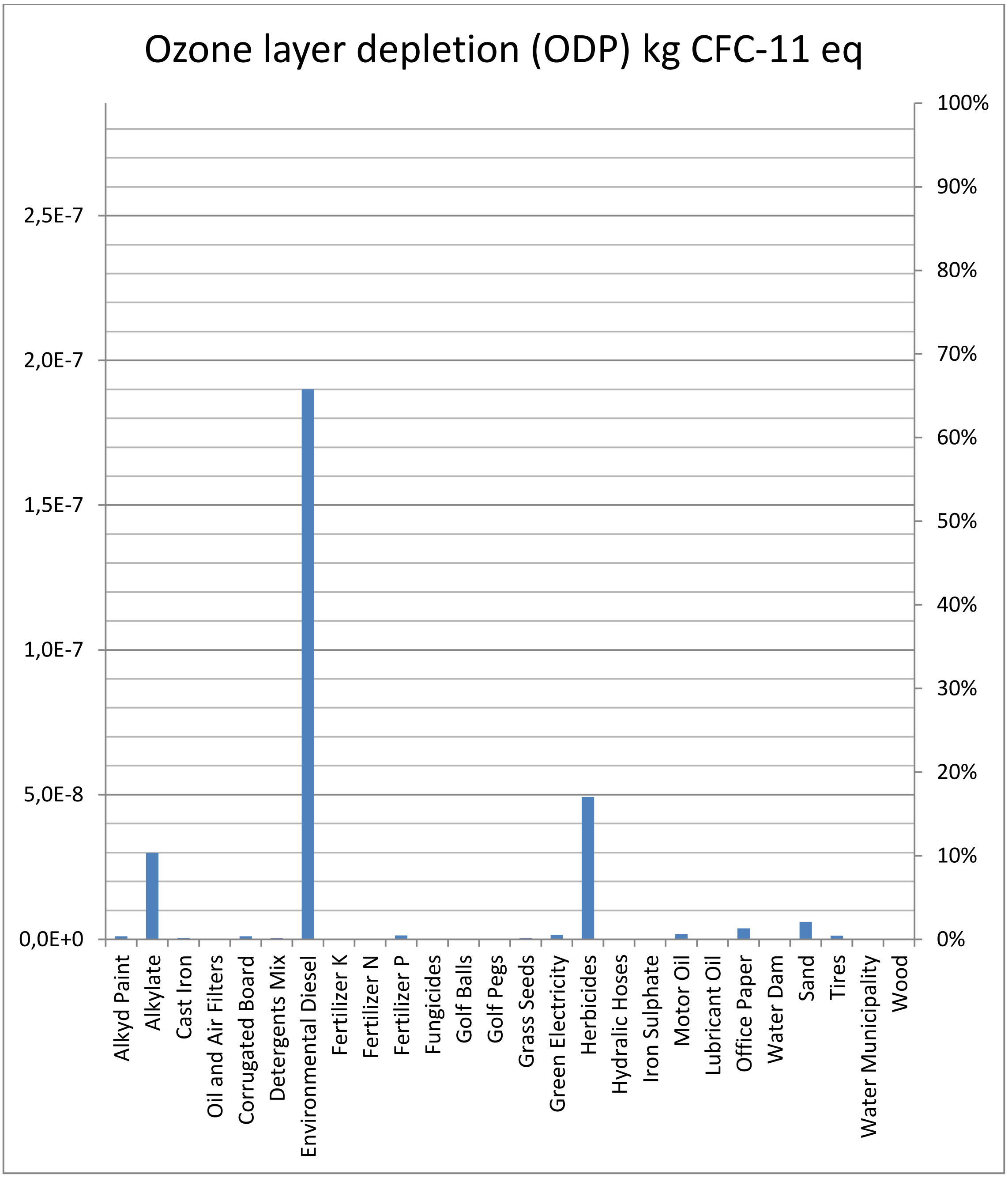


Figure 12: The ozone depletion potential for Forsgården GK.

One 18-hole round at Forsgården GK contributes to the ozone depletion with 2.9E-7 CFC-11 equivalents. Environmental diesel is the resource with the most significant impact with 1.9E-7 CFC-11 eq and 66% of the total ozone depletion potential. Sand, office paper, herbicides and alkylate are above the 1% limit.

4. LCA of Two Fictive Golf Clubs

The identified differences in golf course management are described and subsequently the two LCA studies, Best Case GK and Worst Case GK, are presented. The resource uses in Best Case GK and Worst Case GK have been based on the identified differences in golf course management described below.

4.1 Differences Between Golf Courses in Sweden

The most obvious difference between golf courses in Sweden is the different climate zones. There is a big difference in latitude between northern Sweden and southern Sweden which results in big differences in the climate. But there are also differences in littoral and inland climate. The length of the gaming season differs a lot between the different climate zones, some golf clubs located in southern Sweden in a littoral climate are open throughout the year while other golf clubs located in northern Sweden in inland climate only have a gaming season of 20 weeks. The gaming season usually ranges from 20 to 40 weeks in Sweden.

The difference in gaming season influences the resource use on the golf club but also the number of golf rounds played per year. Shorter season implies lower resource use and fewer golf rounds. Since the environmental impact is calculated per functional unit the difference in length of the gaming season will not create big differences in the result and does therefore not affect the screening mentionable. Although, differences in rounds per year affects the result, golf courses with the same resource use but different number of played rounds will get different results. More rounds will result in lower impact per golf round. The number of golf rounds is the same for all the three LCA studies in order to be comparable.

The gaming season is not the only thing affected by the differences in climate, the management of the turf differs. In northern Sweden the winters are harder which have made some golf clubs use winter covers on their golf courses. The winter cover is made of polyethylene (Covermaster, n.d.).

Different types of grass require different types of management, there are grass that grows slower, require less water, fertilizers and pesticides. Other types of grass are more resource intense. Depending on the grass chosen the need of water, fertilizers, pesticides and the periodicity of grass mowing, indirectly the fossil fuel use, varies between golf clubs. Some golf clubs do not have much water in their own dams and are from times to times forced to irrigate their golf course with municipal water.

Also the machinery fleet differs depending on many variables such as size of the golf course and economy. For example an older fleet tends to have higher fuel consumption. Also the distribution between the different fossil fuels can differ, for instance some golf clubs might use a higher share of alkylate than diesel compared to other golf clubs. Electricity consumption also differs depending on heating system, climate etcetera.

Which electricity is chosen also result in different impacts, green electricity mix will give a lower environmental impact.

The attitude among stakeholders differs a lot between different parts in Sweden. In some parts there are high expectations on the golf course turf, the turf should be perfect and flawless while in other parts, the expectations are considerably lower. Higher expectations on the turf often cause more intense turf maintenance. Attitudes towards pesticides also differ between the different parts, with some golf courses more liberal than others. High expectations often coincide with a more liberal attitude towards pesticide use.

4.2 Results of the Inventory Analysis of Best Case GK and Worst Case GK

Best Case GK and Worst Case GK are two fictive golf clubs and an LCA study has been performed on both of them. The system for Best Case GK and Worst Case GK is assumed to be the same as for Forsgården GK, and so are also the main activities. The size of the golf courses are the same as for Forsgården GK, 95 ha, and also the number of rounds is the same, 40 000 rounds.

The main activity Operation of Golf Course includes the same activities for both Best Case GK and Worst Case GK, except for one addition to Worst Case GK, winter covers. For Worst Case GK the greens are assumed to be covered in the winter in order to protect the turf. The area of the greens is the same as for Forsgården GK, 2.2 ha.

Best Case GK is a possible future golf course. The mowers for Best Case GK differ from Forsgården GK and Worst Case GK; all the mowers are electric and therefore no diesel or alkylate consumption occurs at Best Case GK. The electricity mix used at Best Case GK is the same as for Forsgården GK, a mix of 90% hydropower and 10% wind power. All along the line Best Case GK use a minimal of all the other resources. The turf on Best Case GK is assumed to be very tough with little need of irrigation, fertilizing, aerification etc. The sand consumption is also lower due to little need of dressing and the sand is bought from a local supplier only 10 km away. Pesticides are not used at all.

Worst Case GK on the other hand has higher resource consumption than Forsgården GK. The turf at Worst Case GK requires extensive care with high intensity of mowing, irrigating, aerification, dressing etcetera. A lot of fertilizers and pesticides are used and reseeding is often needed since the turf dies in patches. The electricity used at Worst Case GK is Swedish Electricity Mix, referred to Electricity, which besides hydropower and wind power also include and other renewables and nuclear power, fossil fuels.

The main activity Maintenance of Equipment does not differ much from Forsgården GK, except from the rinsing of mowers. Since mowing is not done as frequently at Best

Case GK the mowers is rinsed much more seldom. For Worst Case GK it is the opposite, since the turf is mowed very frequently that is also the case for rinsing.

The main activity Operation of Buildings and Infrastructure differs between the golf clubs. Electricity consumption differs, because of differences in heating and insulation but also other energy saving methods. Also Best Case GK and Worst Case GK use different electricity mixes. Best Case GK uses electricity very sparingly while Worst Case GK uses the electricity much more prodigally. The office work also differ, Worst Case GK uses a lot of office paper while Best Case GK has minimized their use.

The main activity Golfing does not differ that much between the golf clubs. The number of pegs lost at the courses is the same for all three; Forsgården GK, Best Case GK and Worst Case GK. The numbers of golf balls lost are twice as many at Worst Case GK than it is at Forsgården GK or at Best Case GK.

The resources used are the same at all three golf clubs except for Worst Case GK where also winter covers are used. All the resources and the amount of resources used are presented in the following section.

4.2.1 Resources and Related Amounts for Best Case GK and Worst Case GK

All resources and the amount used in golf course management for Best Case GK and Worst Case GK are presented in the table 14 below. All the assumptions made regarding the amount used are presented in Appendix VI. The resources correspond to resources in SimaPro which are presented in Appendix V.

Resource	Best Case GK	Worst Case GK	Unit
Alkylate	0	3 750	kg
Anti-rust Agent	32	32	kg
Cast Iron	97	666	kg
Corrugated Board	308	862.4	kg
Course Marks	1	1	m^3
Detergent Mix	210	420	kg
Electricity	0	420 880	kWh
Enamel Paint	32	32	kg
Environmental Diesel	0	20 000	kg
Fertilizer K	257	1 540	kg
Fertilizer N	710	4 264	kg
Fertilizer P	737	4 422	kg
Fungicides	0	4.8	kg
Golf Balls	40 000	120 000	pieces
Golf Pegs	80 000	80 000	pieces
Grass Seeds	50	200	kg
Green Electricity	154 220	0	kWh
Herbicides	0	160	kg
Hydraulic Hoses	16	16	kg
Iron Sulphate	150	900	kg
Lubricant Oil	8	8	l
Motor Oil	85	142	kg
Office Paper	539	1 509.2	kg
Oil and Air Filters	5	5	kg
Sand	400	1 500	ton
Tires	32	128	pieces
Water, Dam	35 000	20 000	m^3
Water, Municipality	500	20 000	m^3
Winter Cover	0	220	kg
Wood Paint	2	2	kg

Table 3: The amount of the different resources used at Best Case and Worst Case.

4.3 Results of the Impact Assessment of Best Case GK and Worst Case GK

The characterization for Best Case GK and Worst Case GK are presented in this section.

4.3.1 Characterisation

The characterized results of Best Case GK and Worst Case GK are presented for each of the impact categories. A limit is set at 1% for all the charts, the same as for Forsgården GK. The total amount of impact equivalents (eq) can be found in Appendix I.

4.3.1.1 Global Warming Potential

Best Case GK

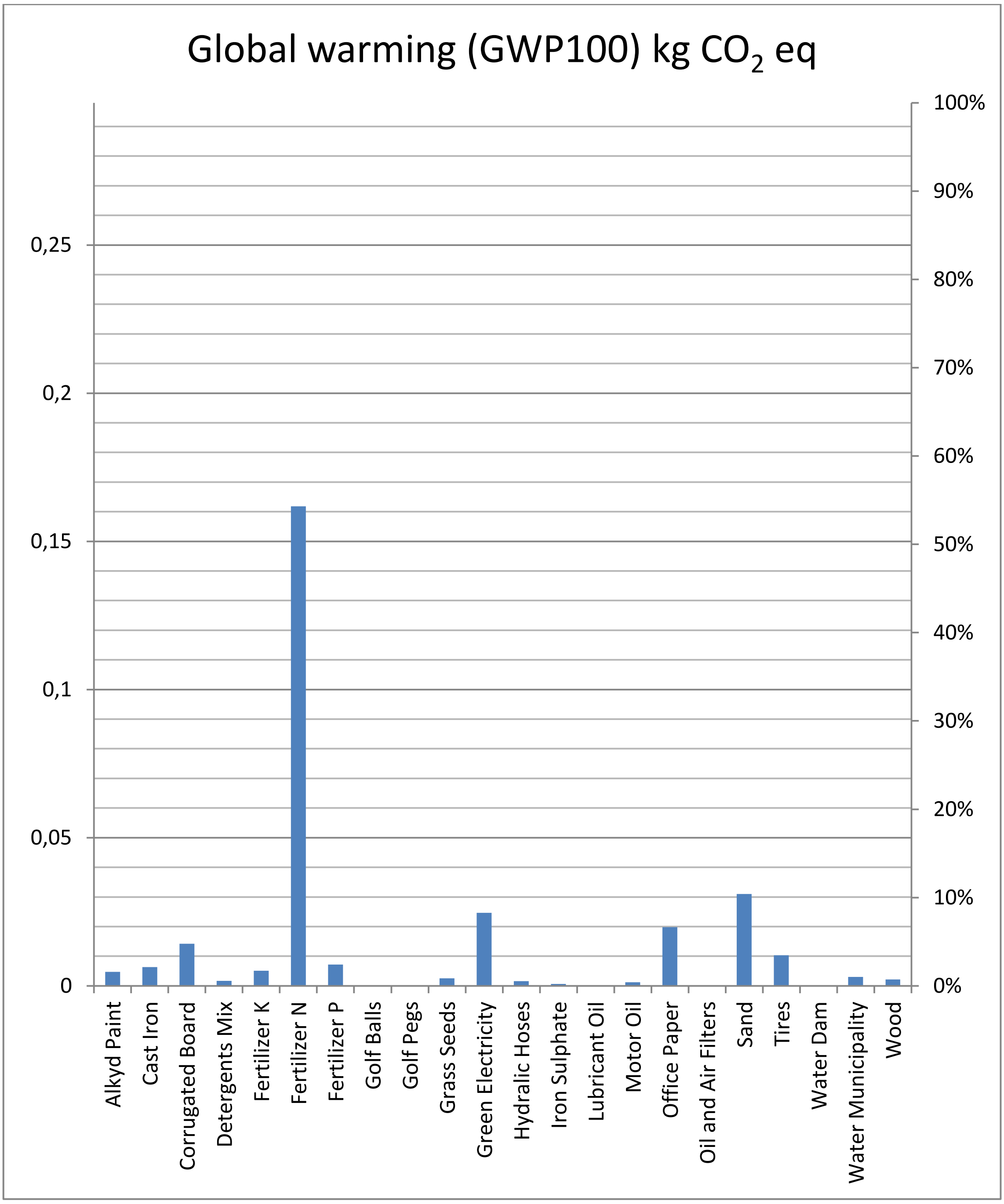


Figure 13: The global warming potential for Best Case GK.

One 18-hole round at Best Case GK contributes to the global warming potential with 0.30 kg CO_2 equivalents. The resource that has the most significant impact is fertilizer N with 0.16 kg CO_2 representing 54%. More resources are above the 1% limit; i.e. cast iron, alkyd paint, sand, corrugated board, office paper, fertilizer P, fertilizer K, electricity, tires and water municipality.

Worst Case GK

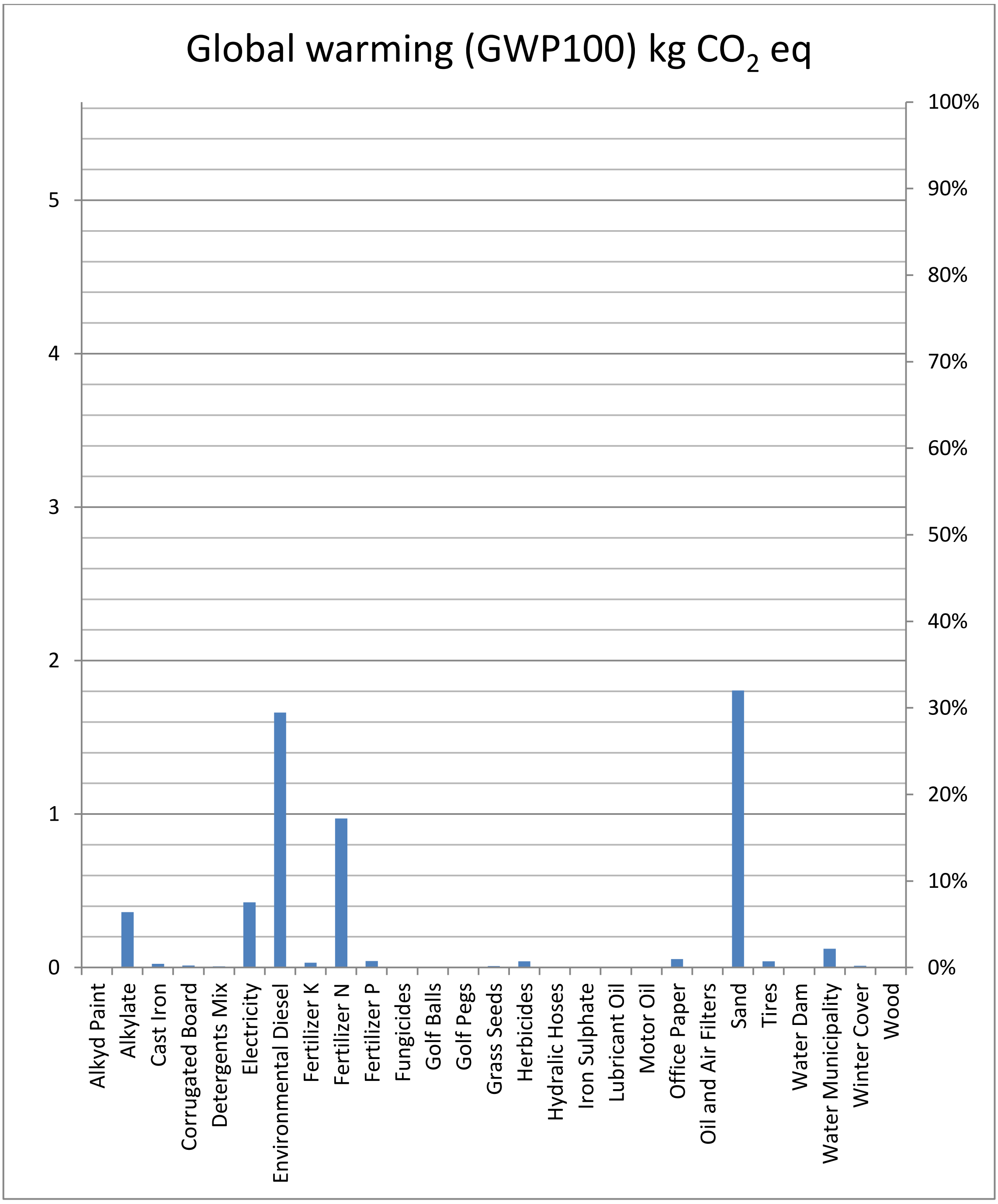


Figure 14: The global warming potential for Worst Case GK.

One 18-hole round at Worst Case GK contributes to the global warming potential with 5.64 kg CO_2 equivalents. Sand has a large impact due to long transportation distance and represents 32% with 1.81 kg CO_2 eq. Environmental Diesel has 1.66 kg CO_2 eq and 29% of the total contribution. Fertilizer N, electricity, environmental diesel, alkylate and water municipality are also above the 1% limit.

4.3.1.2 Acidification Potential

Best Case GK

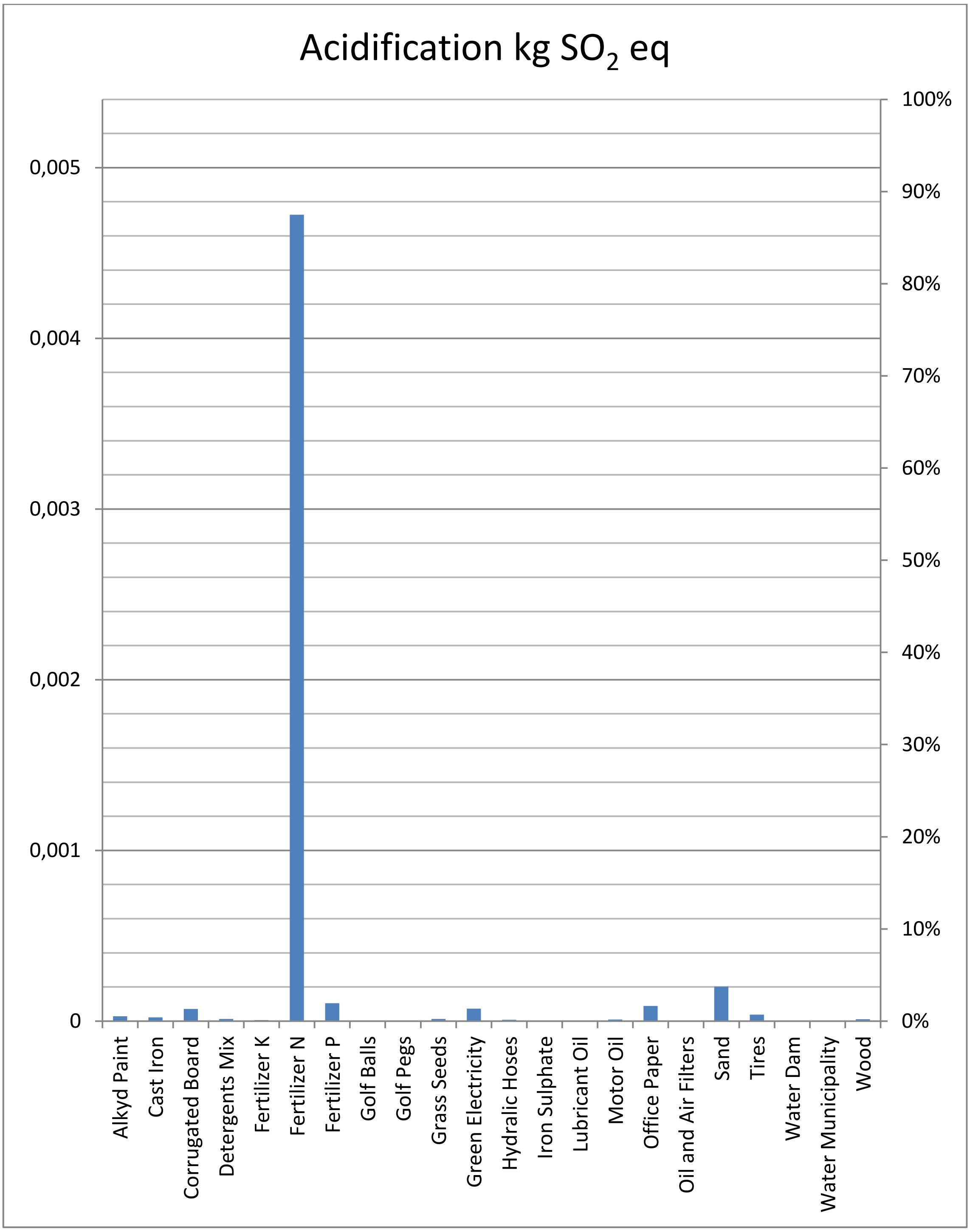


Figure 15: The acidification potential for Best Case GK.

One 18-hole round at Best Case GK contributes to the acidification with 0.0054kg SO_2 equivalents. Fertilizer N with 87% of the acidification potential is by far the most significant contributor. Sand, corrugated board, office paper, fertilizer P and electricity are also above the 1% limit.

Worst Case GK

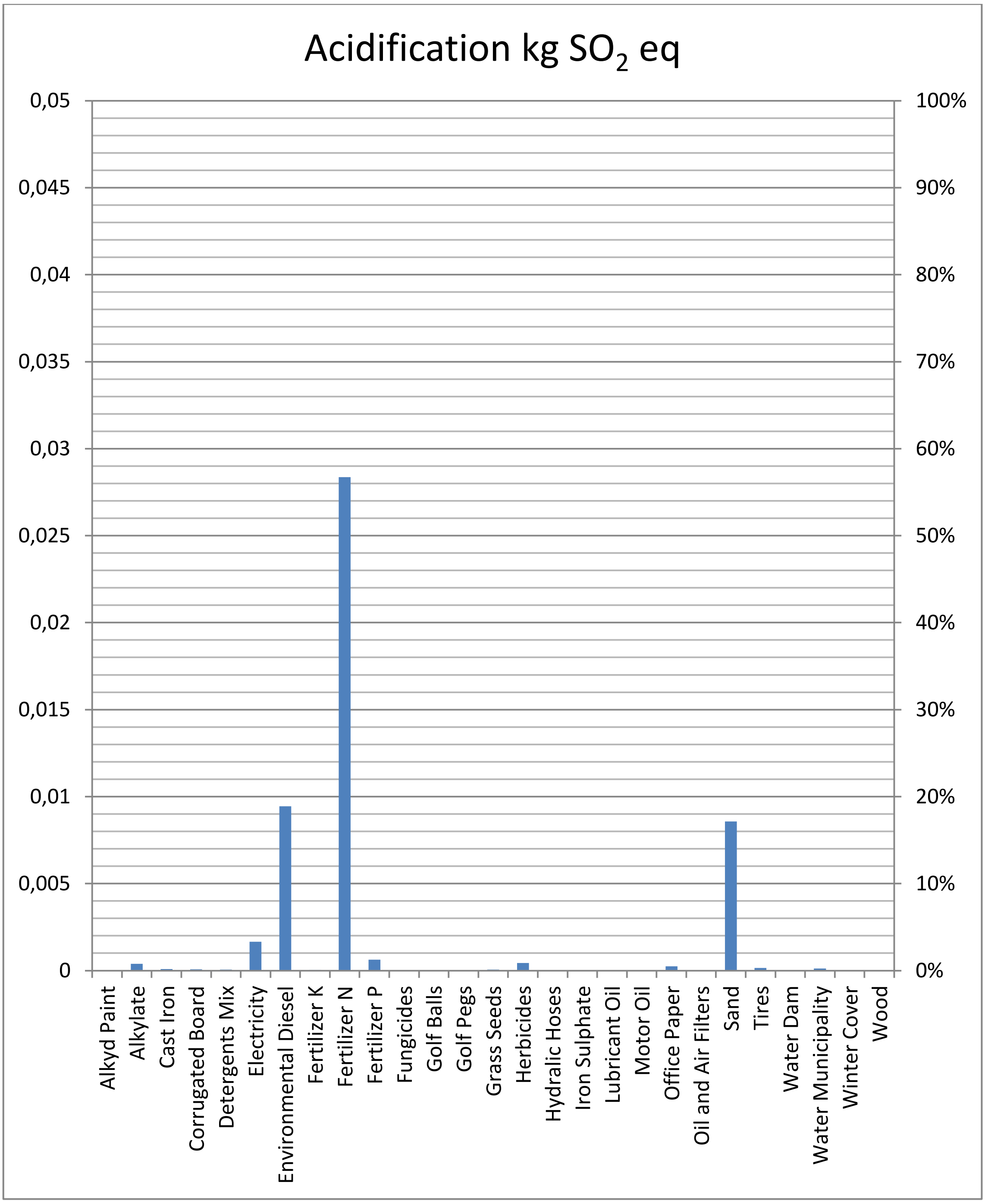


Figure 16: The acidification potential for the Worst Case GK.

One 18-hole round at Worst Case GK contributes to the acidification with 0.051 kg SO_2 equivalents. The biggest contributor to acidification for Worst Case GK is fertilizer N with 0.0028 kg SO_2 eq which represents 56%. Sand, fertilizer P, electricity and environmental diesel are above the 1% limit.

4.3.1.3 Eutrophication Potential

Best Case GK

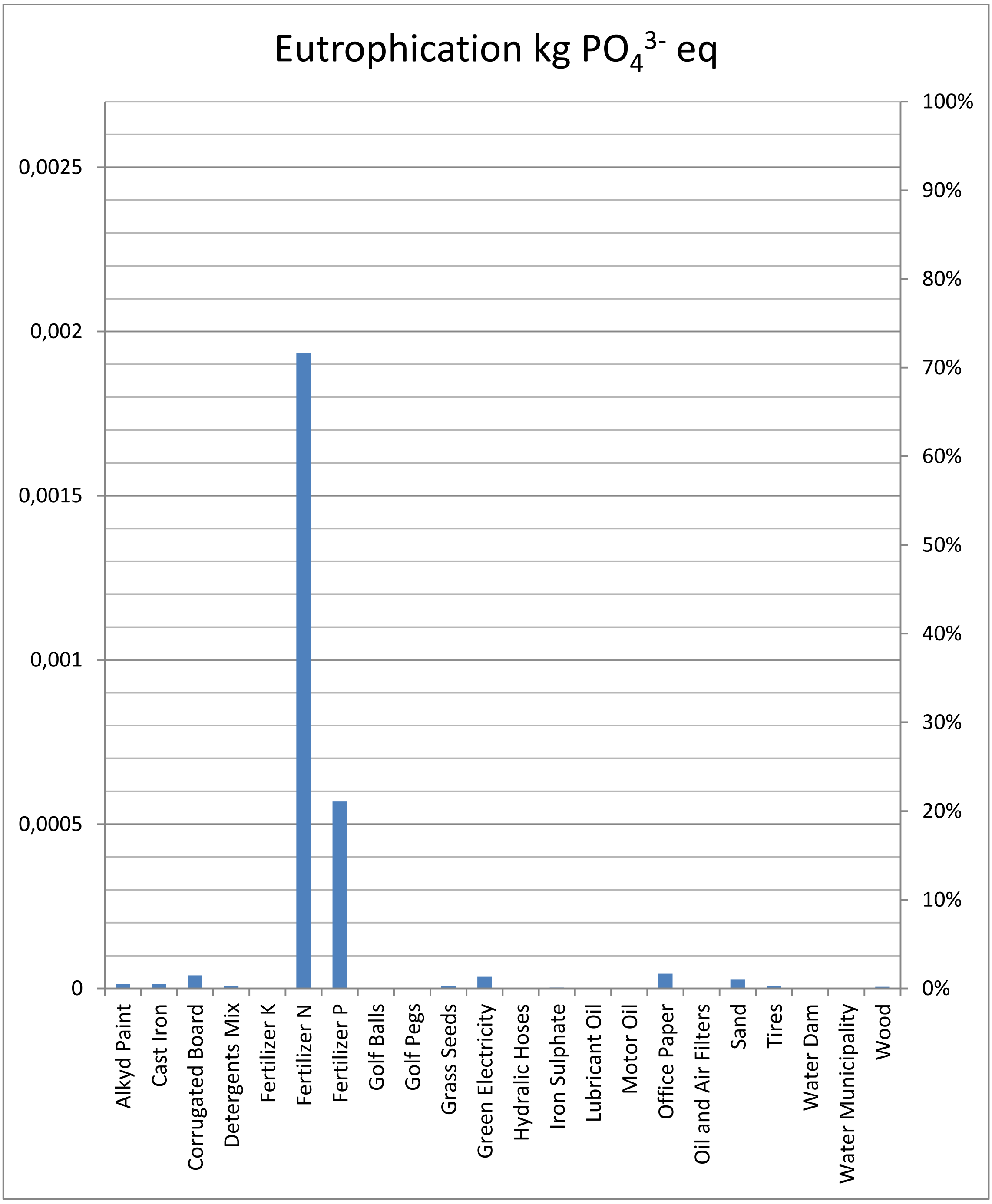


Figure 17: The eutrophication potential for Best Case GK.

One 18-hole round at Best Case GK contributes to the eutrophication with of 0.0027 PO_4^{3-} equivalents. The resources above the 1% are fertilizer N, fertilizer P, corrugated board, electricity, office paper and sand.

Worst Case GK

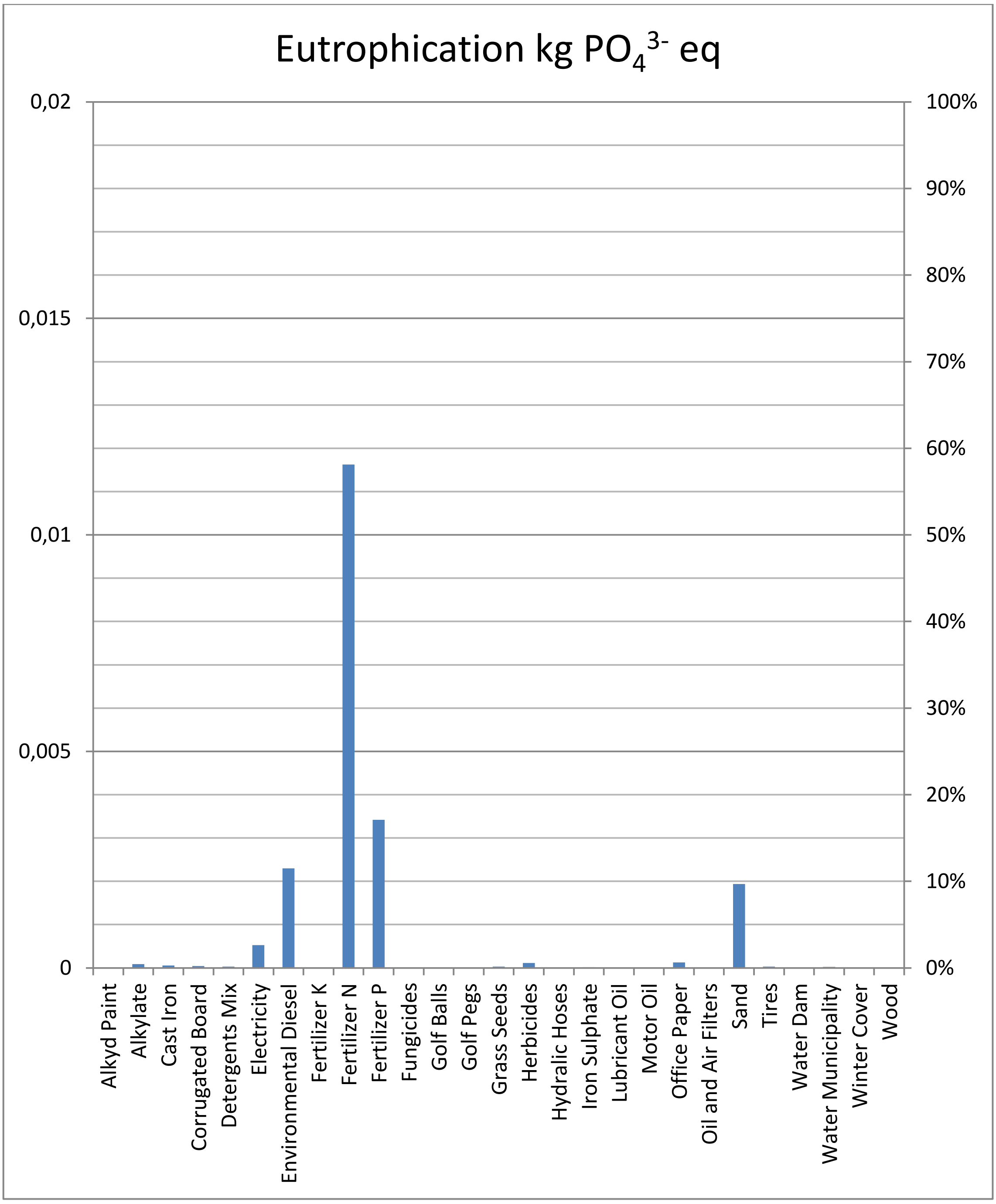


Figure 18: The eutrophication potential for Worst Case GK.

One 18-hole round at Worst Case GK contributes to the eutrophication with of 0.02 PO_4^{3-} equivalents. Fertilizer P and fertilizer N have the largest impact with an aggregated contribution of 74%. Fertilizer P has 0.0034kg PO_4^{3-} eq and Fertilizer N 0.012 kg PO_4^{3-} eq. Sand, electricity and environmental diesel are above the 1% limit.

4.3.1.4 Photochemical Oxidation Potential

Best Case GK

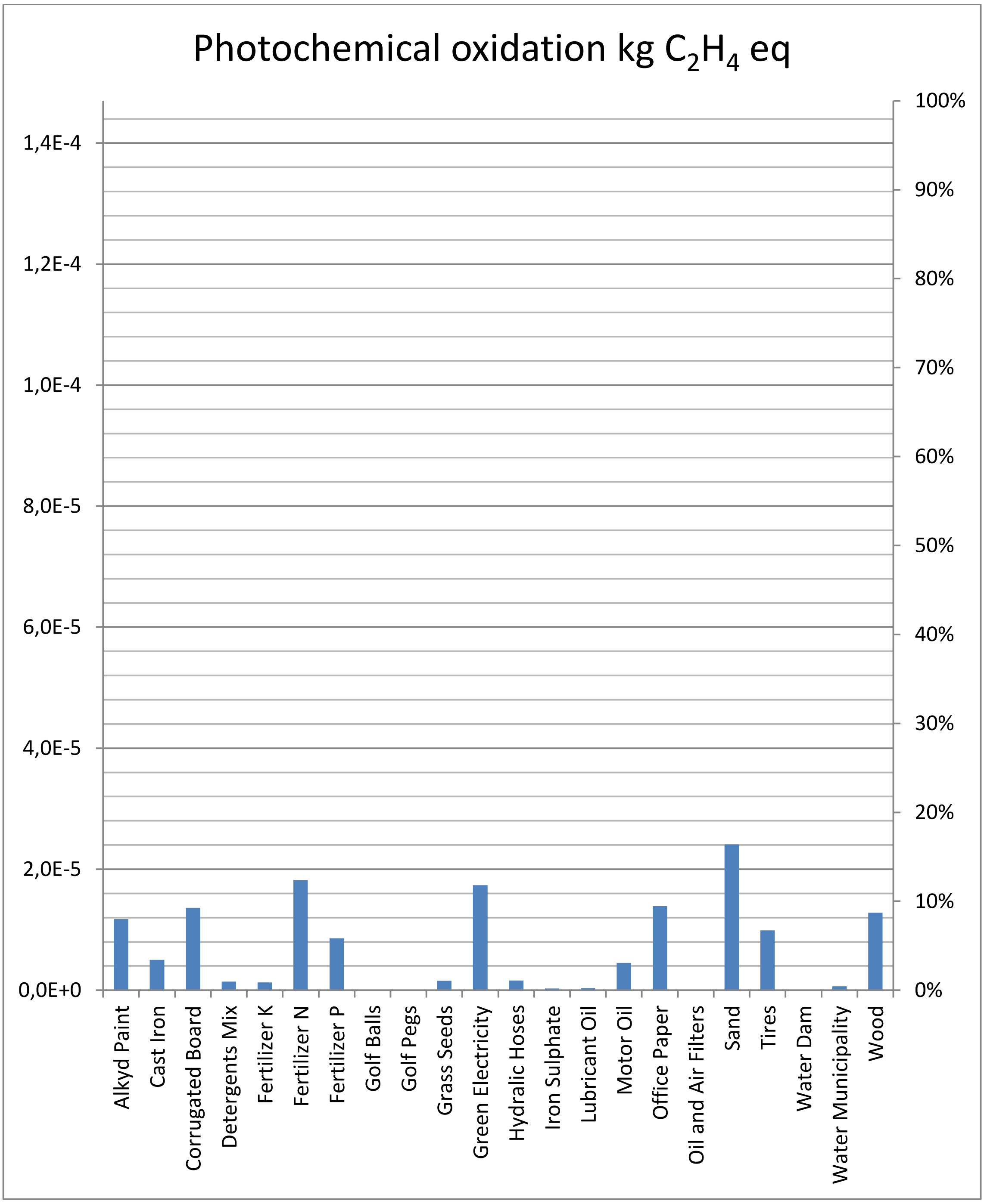


Figure 19: The photochemical oxidation potential for Best Case GK.

One 18-hole round at Best Case GK contributes to the photochemical oxidation potential with 0.00015 kg C_2H_4 equivalents. The contribution of impact is relatively evenly distributed between the resources and many resources are above the 1% limit. Cast iron, motor oil, alkyd paint, sand, grass seeds, corrugated board, office paper, fertilizer N fertilizer P, electricity, tires, and wood (course marks) are above the 1% limit.

Worst Case GK

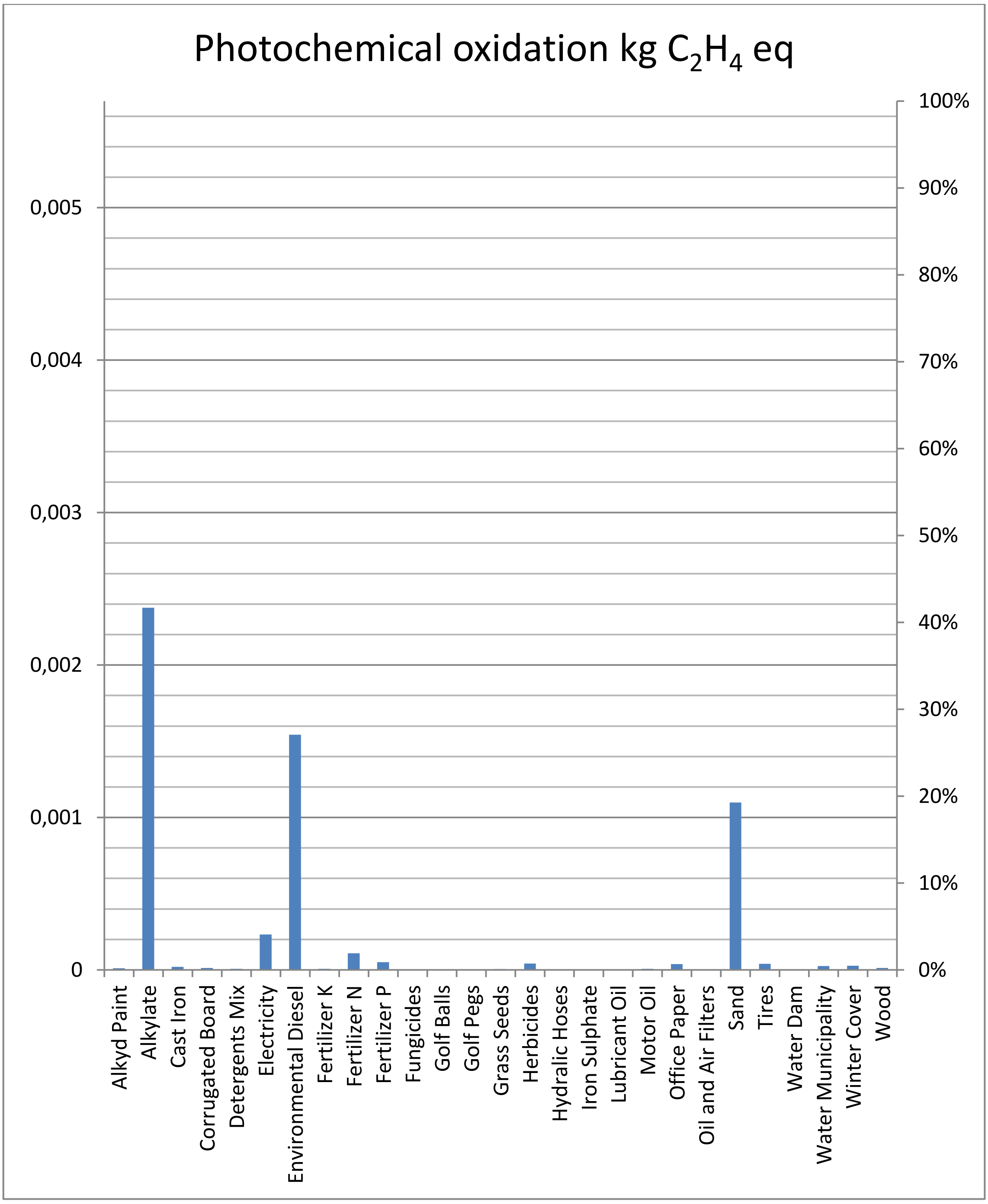


Figure 20: The photochemical oxidation potential for Worst Case GK.

One 18-hole round at Worst Case GK contributes to the photochemical oxidation potential with 0.0057 kg C_2H_4 equivalents. The largest contributor is alkylate with 0.0024 kg C_2H_4 eq and 42%. Sand, fertilizer N, electricity and environmental diesel (MK1) are above the 1% limit.

4.3.1.5 Ozone Depletion Potential

Best Case GK

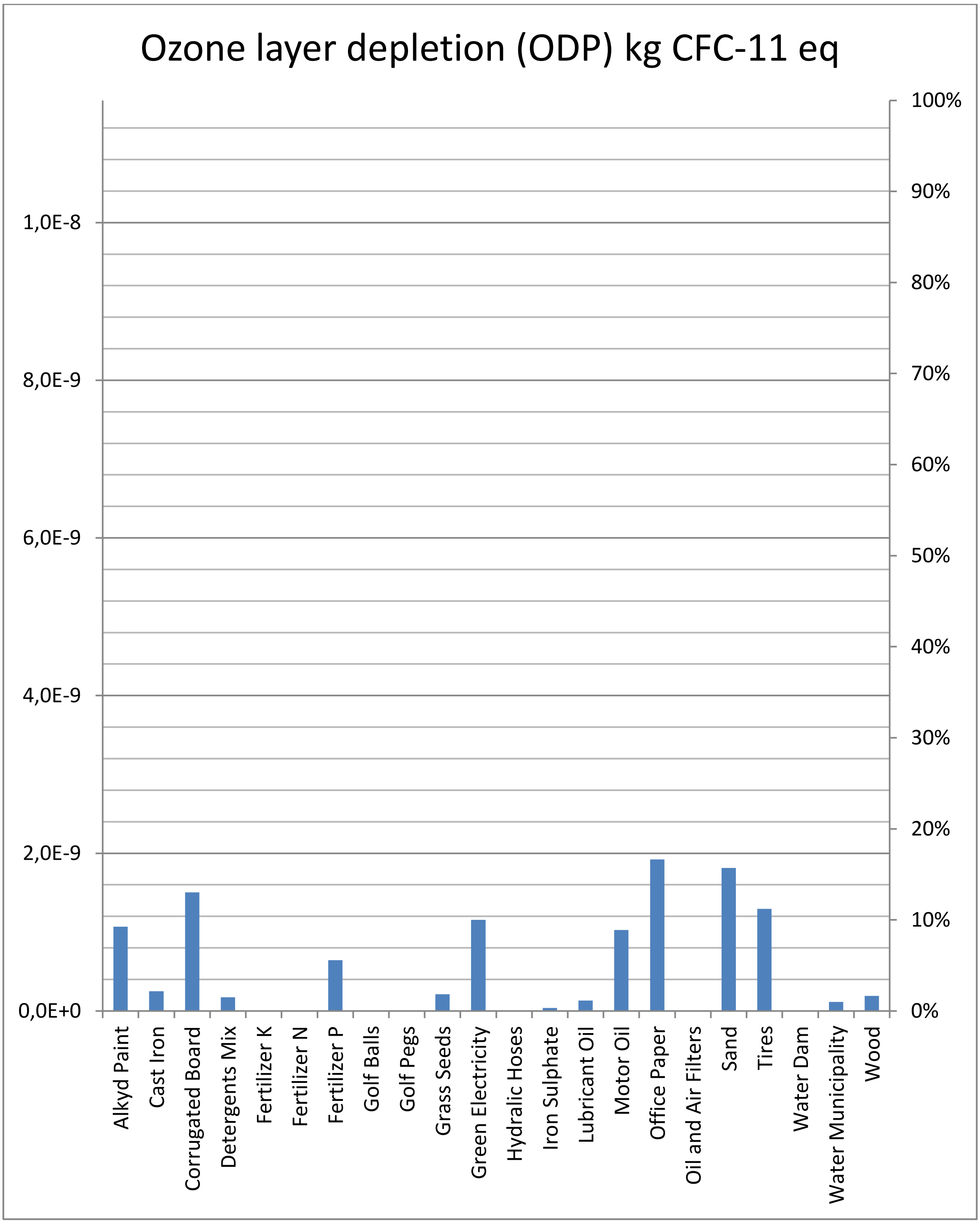


Figure 21: The ozone depletion potential for Best Case GK.

One 18-hole round at Best Case GK contributes to the ozone depletion potential with 1.15E-8 CFC-11 equivalents. As for photochemical oxidation potential the distribution between the resources impact is relatively even. Above the 1% limit are; motor oil, alkyd paint, cast iron, grass seeds, sand, corrugated board, office paper, lubricant oil, fertilizer P, detergent mix, electricity, tires and wood (course marks).

Worst Case GK

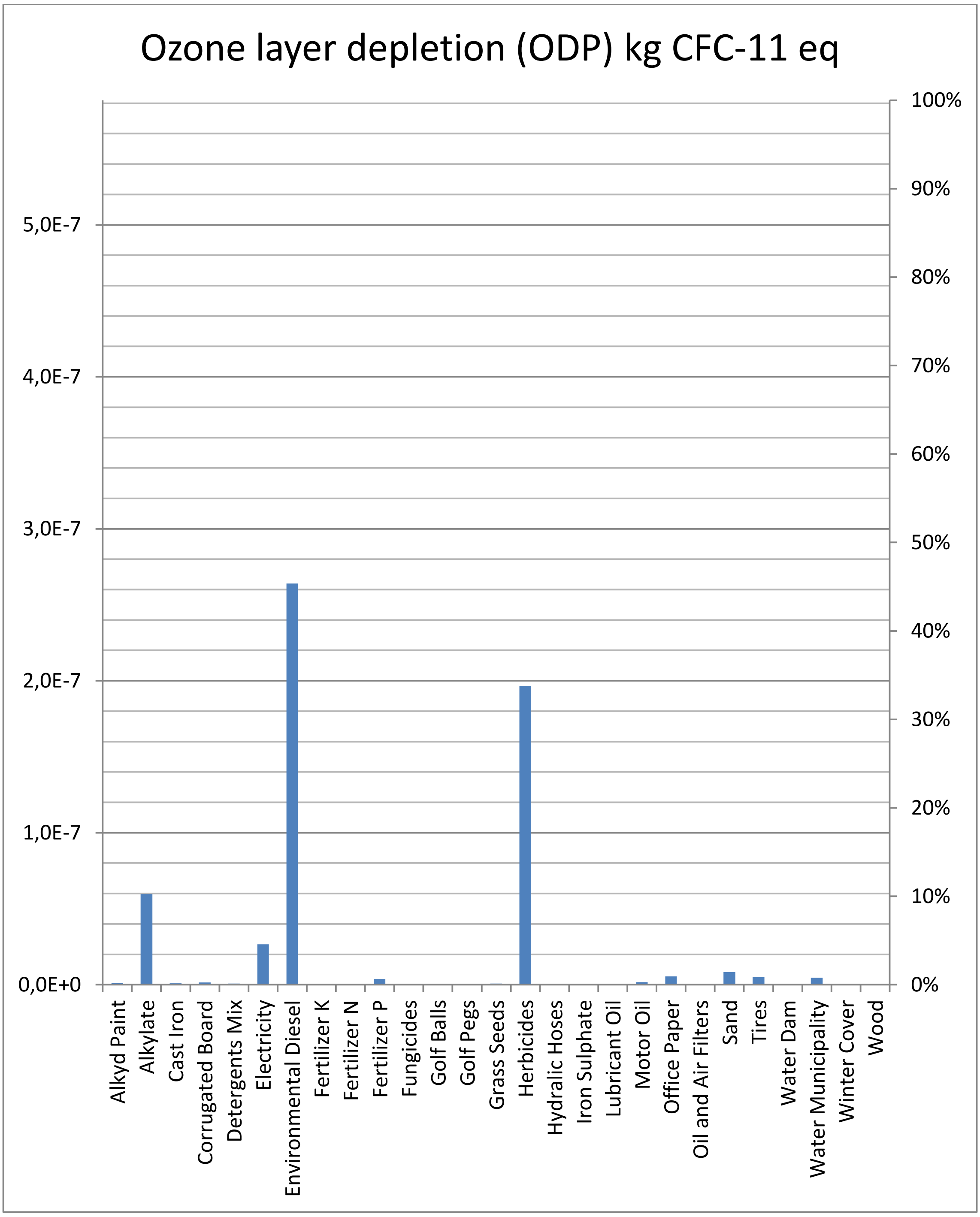


Figure 22: The ozone depletion potential for Worst Case GK.

One 18-hole round at Worst Case GK contributes to the ozone depletion potential with 5.8E-7 CFC-11 equivalents. Environmental diesel and herbicides are the largest contributors with 2.6E-7 CFC-11 eq and 2.0E-7 CFC-11 eq contributing with 45% and 34% of the total impact. Above the 1% limit are sand, electricity and alkylate.

5. Identified Hotspots

Resources above the limit, possible hotspots and the final hotspots are presented in this section.

5.1 Resources Above the Limit

The characterization results of the tree LCA studies; Forsgården GK, Best Case GK and Worst Case GK, are the foundation for the identification of the hotspots. The hotspots are the resources used in golf course operation resulting in the largest environmental impacts. The relative contributions of emissions for each of the LCA studies have been analyzed for all the impact categories and resources resulting in relative emissions higher than 1 % are marked with an “X” in the tables.

Global Warming Potential

	Forsgården GK	Best Case GK	Worst Case GK
Alkyd Paint		x	
Alkylate	x		x
Cast Iron		x	
Corrugated Board		x	
Course Marks			
Detergent Mix			
Electricity			x
Enamel Paint			
Environmental Diesel	x		x
Fertilizer K		x	
Fertilizer N	x	x	x
Fertilizer P		x	
Fungicides			
Golf Balls			
Golf Pegs			
Grass Seeds			
Green Electricity	x	x	
Herbicides			
Hydraulic Hoses			
Iron Sulphate			
Lubricant Oil			
Motor Oil			
Office Paper	x	x	
Sand	x	x	x
Tires		x	
Water, Dam			
Water, Municipality		x	x
Winter Cover			

Table 4: Table for determining hotspots for the global warming potential.

Ozone Depletion Potential

	Forsgården	Best case	Worst case
Alkyd Paint		x	
Alkylate	x		x
Cast Iron		x	
Corrugated Board		x	
Course Marks		x	
Detergent Mix		x	
Electricity			x
Environmental Diesel	x		x
Fertilizer K			
Fertilizer N			
Fertilizer P		x	
Fungicides			
Golf Balls			
Golf Pegs			
Grass Seeds		x	
Green Electricity		x	
Herbicides	x		x
Hydraulic Hoses			
Iron Sulphate			
Lubricant Oil		x	
Motor Oil		x	
Office Paper	x	x	
Oil and Air Filters			
Sand	x	x	x
Tires		x	
Water, Dam			
Water, Municipality			
Winter Cover			

Table 5: Table for determining hotspots for the ozone depletion potential.

Photochemical Oxidation Potential

	Forsgården GK	Best case GK	Worst case GK
Alkyd Paint		x	
Alkylate	x		x
Cast Iron		x	
Corrugated Board		x	
Course Marks		x	
Detergent Mix			
Electricity			x
Environmental Diesel	x		x
Fertilizer K			
Fertilizer N	x	x	x
Fertilizer P		x	
Fungicides			
Golf Balls			
Golf Pegs			
Grass Seeds		x	
Green Electricity		x	
Herbicides			
Hydraulic Hoses		x	
Iron Sulphate			
Lubricant Oil			
Motor Oil		x	
Office Paper	x	x	
Oil and Air Filters			
Sand	x	x	x
Tires		x	
Water, Dam			
Water, Municipality			
Winter Cover			

Table 6: Table for determining hotspots for the photochemical oxidation potential

Acidification Potential

	Forsgården GK	Best case GK	Worst case GK
Alkyd Paint			
Alkylate			
Cast Iron			
Corrugated Board		x	
Course Marks			
Detergent Mix			
Electricity			x
Environmental Diesel	x		x
Fertilizer K			
Fertilizer N	x	x	x
Fertilizer P		x	x
Fungicides			
Golf Balls			
Golf Pegs			
Grass Seeds			
Green Electricity		x	
Herbicides			
Hydraulic Hoses			
Iron Sulphate			
Lubricant Oil			
Motor Oil			
Office Paper		x	
Oil and Air Filters			
Sand	x	x	x
Tires			
Water, Dam			
Water, Municipality			
Winter Cover			

Table 7: Table for determining hotspots for the acidification potential.

Eutrophication Potential

	Forsgården GK	Best case GK	Worst case GK
Alkyd Paint			
Alkylate			
Cast Iron			
Corrugated Board		x	
Course Marks			
Detergent Mix			
Electricity			x
Environmental Diesel	x		x
Fertilizer K			
Fertilizer N	x	x	x
Fertilizer P	x	x	x
Fungicides			
Golf Balls			
Golf Pegs			
Grass Seeds			
Green Electricity		x	
Herbicides			
Hydraulic Hoses			
Iron Sulphate			
Lubricant Oil			
Motor Oil			
Office Paper		x	
Oil and Air Filters			
Sand	x	x	x
Tires			
Water, Dam			
Water, Municipality			
Winter Cover			

Table 8: Table for determining hotspots for the eutrophication potential.

Resources marked with two or more "X:es" in one or more of the tables presented earlier are definitive hotspots while resources not marked in any of the tables are considered as no hotspots. The definitive hotspots are; sand, office paper, fertilizer N, fertilizer P, alkylate, green electricity, environmental diesel, herbicides and water municipality. Resources that are considered as no hotspots are; fungicides, golf balls, golf pegs, iron sulphate, oil and air filters, water dam, water municipality and winter cover. Petrol and regular diesel are not included in the LCA studies, but some golf courses might use petrol instead of alkylate and diesel instead of environmental diesel and therefore petrol and diesel are considered as hotspots.

5.2 Possible Hotspots

Resources marked with only one “X” in one or more of the tables 4-8 are considered as possible hotspots. These possible hotspots are determined whether they are hotspots or not in this section.

Alkyd Paint: The alkyd paint is assumed to be used for anti-corrosive treatment of the mowers and also for painting the sticks used for marking the golf course. Alkyd paint is over the 1% limit only for the LCA of Best Case GK and is therefore not considered a hotspot.

Cast Iron: Cast iron is metal scrap. Cast iron is over the 1% limit only for the LCA of Best Case GK and is therefore not considered a hotspot.

Corrugated Board: Corrugated board is only over the 1% limit for the LCA of Best Case GK, therefore the corrugated board is not considered a hotspot.

Course Marks: The course marks are over the 1% limit only for the LCA of Best Case GK and are therefore not considered a hotspot.

Detergent: The detergent is over the 1% limit only Best Case GK and is therefore not considered a hotspot.

Electricity: Since green electricity is one of the definitive hotspots electricity is also considered a hotspot.

Fertilizer K: The potassium fertilizer is over the 1% limit only in the LCA of Best Case and is therefore not considered a hotspot.

Grass Seeds: The grass seeds are over the 1% limit only in Best Case GK and are therefore not considered a hotspot.

Hydraulic Hoses: The hydraulic hoses are over the 1% limit only in Best Case GK and are therefore not considered a hotspot.

Lubricant Oil: The lubricant oil is over the 1% limit only in the LCA of Best Case and is therefore not considered a hotspot.

Motor Oil: The motor oil is over the 1% limit only for the LCA of Best Case GK and is therefore not considered a hotspot.

Tires: Tires on golf course operation vehicles are replaced frequently. Tires are over the 1% limit only in the LCA of Best Case GK and are therefore not considered a hotspot.

5.3 Final Hotspots

The final hotspots include all definitive hotspots and the possible hotspots which are considered as hotspots. The final hotspots are:

Alkylate
Diesel
Electricity
Environmental Diesel
Fertilizer N
Fertilizer P
Green Electricity
Herbicides
Office Paper
Petrol
Sand
Water Municipality

6. Screening of the Golfer's Environmental Impact

A golfer can be associated with other activities connected to golfing. The two identified activities which can be associated with the golfer and golfing is transportation back and forth to the golf course and use of equipment. These two activities are part of the screening and the results are presented below.

6.1 Transportation

A common means of transportation back and forth to the golf course is by car. A normal sized Swedish car emits 156 g CO_2/km (SITA, 2012). The amount of SO_2 that is emitted is 0.00746 g SO_2/km (NyTeknik, 2008). Euro III personal cars have a limit of 0.15 NO_x/km (IVL Swedish Environmental Research Institute Ltd, 2004). 1 g NO_x equals 0.13 g PO_4^{3-} which means that a personal car emits 0.0195 g PO_4^{3-} eq/km (The international EPD system, 2008). The impact of transportation back and forth to the golf course is added to the total impact. Table 9 presents the share between the impact of the golf course and the transportation with the distances 5 km, 10 km and 20 km for one person.

Distance to Forsgården GK	**Global Warming**		**Acidification**		**Eutrophication**	
	Golf Course	**Transport**	**Golf Course**	**Transport**	**Golf Course**	**Transpor t**
5 km	58.98%	41.02%	99.68%	0.32%	97.92%	2.08%
10 km	41.82%	58.18%	99.36%	0.64%	95.93%	4.07%
20 km	26.44%	73.56%	98.73%	1.27%	92.18%	7.82%

Table 9: The amount of impact equivalents for the transportation with a personal car have been added to the total impact for each impact category. The share between the impact from the golf course and the transportation back and forth are presented.

It can be seen from the results that the acidification and eutrophication from the golf course is significantly greater compared to transportation back and forth for the golfer. The share between the impact of the golf course and the transportation can however differ for global warming potential depending on the distance to the golf course and the amount of people riding in the car.

To emit the same amount of CO_2 eq as for Forsgården GK a person have to ride 14.4 km by car. For acidification a person have to go 3110 km by car to emit the same amount. Additionally, a distance of 471 km would have to be driven to emit the same amount of PO_4^{3-} eq as for Forsgården GK.

6.2 Equipment

The equipment used by the golfer such as golf clubs, golf bags, additional golf club covers, clothes, scorecards, umbrellas etcetera are found to have a negligible impact compared to the impact of one 18-hole golf round, since all equipment is either small or used over a long period of time.

However, golf balls and golf pegs are consumed in another magnitude. For the LCA of Best Case GK it is assumed that 1golf ball and 2 pegs are lost each 18-hole round and for Worst Case GK 3 golf balls and the same amount of golf pegs are lost. The LCA studies of the three golf clubs only included the emissions from the decomposition of the golf balls and the golf pegs, production was not included. In the screening of the golfer's environmental impacts the production of the golf balls and golf pegs is included in order to get an understanding whether this is a possible hotspot or not for the golfer. Assumptions regarding the production of the golf balls and the golf pegs are presented in appendix V.

Pegs: 75% of the pegs are made of wood and 25% are made of polypropylene. The emissions related to the pegs are presented in Appendix V. The environmental impact per 18-hole round, per 1 average peg, is:

Global warming	0.00631 kg CO_2 eq
Acidification	1.97E-5 kg SO_2 eq
Eutrophication	2.73E-6 kg PO_4^{3-} eq
Photochemical oxidation	5.27E-6 kg C_2H_4 eq
Ozone layer depletion	5.25E-15 kg CFC-11 eq

Table 10: The estimated environmental impact of pegs.

The impact compared with the result in the three LCA studies performed in this report, did not exceed 1% for any of the categories and is therefore not considered as a hotspot for the golfer.

Golf balls: There is a lack of information about golf ball production, however the production of three layer golf balls may require up to a month, which suggests that the production is a rather intensive process (Advameg Inc, n.d.) (Livestrong.com, 2012). The assumed resource use for production of golf balls is presented in Appendix V. The emissions from the golf balls are assumed to be the same as for the LCA studies of the golf courses.

The results are presented in Table 11 where a range is given, the impact of 1 to 3 balls loss per 18-hole round.

Global warming	0.89- 2.67 kg CO_2 eq
Acidification	0.0022 – 0.0066 kg SO_2 eq
Eutrophication	0.00022 – 0.00065 kg PO_4^{3-}
Photochemical oxidation	0.00066- 0.0020 kg C_2H_4 eq
Ozone layer depletion	1.12E-12 – 3.37 E-10 kg CFC-11 eq

Table 11: The estimated environmental impact of golf balls.

These rough estimates suggest that golf balls with production included are hotspots for the golfer's environmental impact. For the impact category global warming potential the golf balls exceed the limit of 1% for all the golf clubs, Forsgården GK, Best Case GK and Worst Case GK. Based on the assumptions made, the impact of golf balls can be 75% of the total global warming impact for Best Case GK, 28% for Forsgården GK and 32% for Worst Case GK, a definitive hotspot for the golfer.

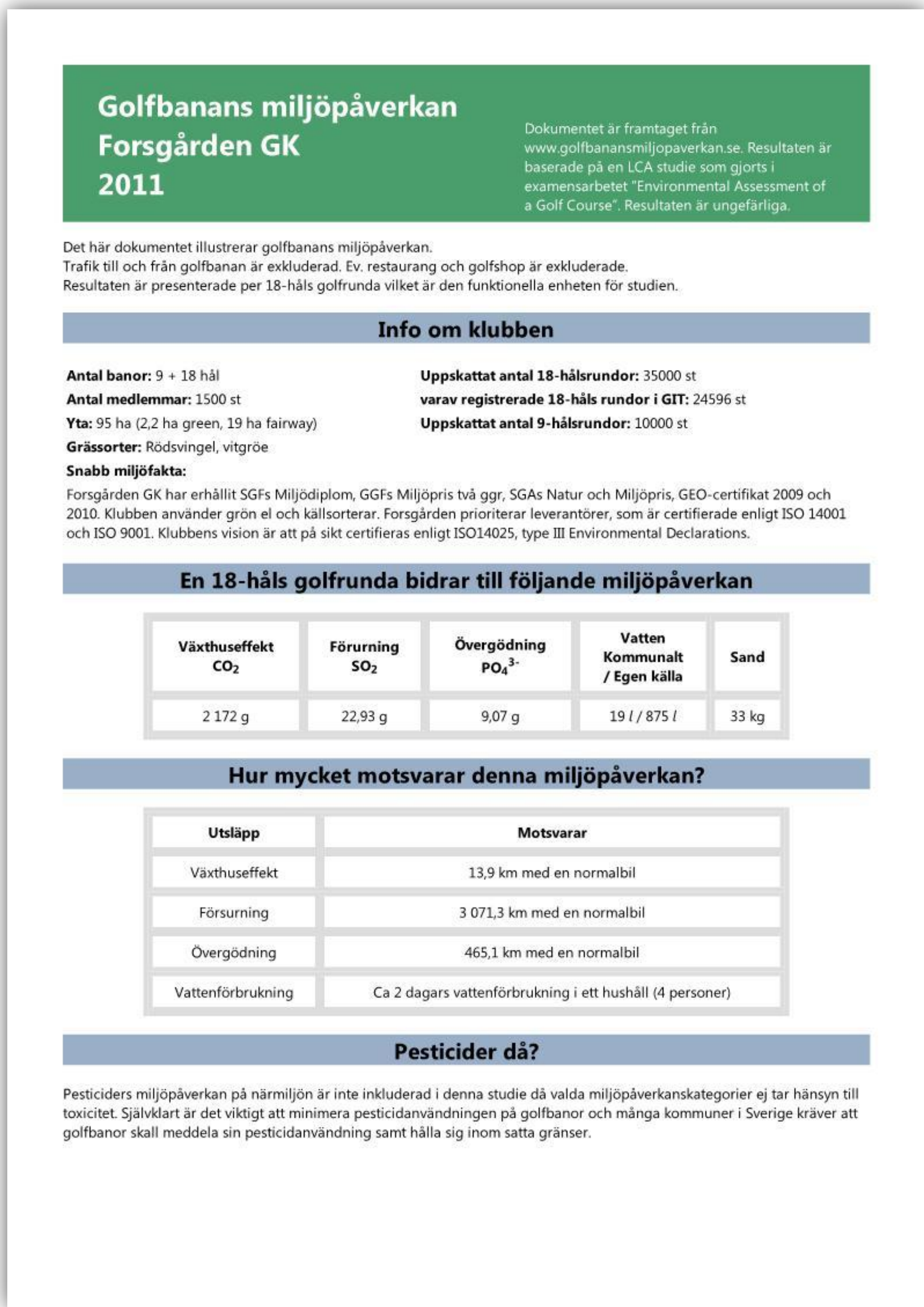
7. The Tool

The tool is to be used by golf clubs in Sweden to simplify their environmental work and to give them a way of communicating their performance to stakeholders such as members, municipalities and the public. It is a web application located at www.golfbanansmiljopaverkan.se. Golf clubs can use this tool to evaluate how a change in their resource use can alter their environmental pressure. The user enters the resource use and the application then generates two documents with the golf club's environmental impact. One of the documents is for golf clubs internal environmental work and the other for communication to stakeholders. These two documents, called environmental impact profile (Miljöpåverkansprofil) in the web application, differs since the information needed for golf clubs internal environmental work is not the same as the information relevant to stakeholders, which is more simplified.

The default view of the webpage is the login page, which includes a login form and short information about the web site. Unauthorized users are not able to view other pages on the website. Therefore the short information displayed includes information about the tool, how it has been developed and what is included, as well as a link to this report. To login to the web site the user has to acquire user information by contacting the one responsible for the web site at SGF.

An authorized user is able to create a new environmental impact profile, by entering general information about the golf club as well as the resource use. The general information is; number of courses, number of members, occupied area, types of grass, estimated amount of 18-hole rounds, registered amount of 18-hole rounds in GIT, estimated amount of 9-hole rounds as well as short environmental facts about the golf club. The resource use, which the user has to enter, is only those resources that were found to be hotspots. It is the resource use for a specific or fictive year. When the user has entered all the information he or she can choose to save, view the short document for communication or view the long document for the golf club internal environmental work.

The short document for communication, generated from the information entered by the user, is simplified and only contains the most important information about the golf clubs environmental performance. It is of high importance to make it as simple and clean as possible since it is assumed that the reader will have little knowledge of environmental assessment and would not be interested in reading the document if there was too much information. Therefore only the impact categories global warming, eutrophication and acidification as well as water and sand consumption are included. Water and sand are presented since golf courses use a lot of these resources. The total amount of impact equivalents are presented as well as what it corresponds to, compared to driving with a normal sized Swedish car. Only presenting the total amount of impact would not give the same information as when put into context. Additionally a section about pesticides is included, since the environmental impact categories are not considering eco toxicity and thus it is important to communicate that there are restrictions about pesticide use. The document as can be created from the web site is displayed in Figure 23.



Golfbanans miljöpåverkan Forsgården GK 2011

Dokumentet är framtaget från www.golfbanansmiljopaverkan.se. Resultaten är baserade på en LCA studie som gjorts i examensarbetet "Environmental Assessment of a Golf Course". Resultaten är ungefärliga.

Det här dokumentet illustrerar golfbanans miljöpåverkan.
Trafik till och från golfbanan är exkluderad. Ev. restaurang och golfshop är exkluderade.
Resultaten är presenterade per 18-håls golfrunda vilket är den funktionella enheten för studien.

Info om klubben

Antal banor: 9 + 18 hål
Antal medlemmar: 1500 st
Yta: 95 ha (2,2 ha green, 19 ha fairway)
Grässorter: Rödsvingel, vitgröe
Uppskattat antal 18-hålsrundor: 35000 st
varav registrerade 18-håls rundor i GIT: 24596 st
Uppskattat antal 9-hålsrundor: 10000 st
Snabb miljöfakta:

Forsgården GK har erhållit SGFs Miljödiplom, GGFs Miljöpris två ggr, SGAs Natur och Miljöpris, GEO-certifikat 2009 och 2010. Klubben använder grön el och källsorterar. Forsgården prioriterar leverantörer, som är certifierade enligt ISO 14001 och ISO 9001. Klubbens vision är att på sikt certifieras enligt ISO14025, type III Environmental Declarations.

En 18-håls golfrunda bidrar till följande miljöpåverkan

Växthuseffekt CO_2	Förurning SO_2	Övergödning PO_4^{3-}	Vatten Kommunalt / Egen källa	Sand
2 172 g	22,93 g	9,07 g	19 *l* / 875 *l*	33 kg

Hur mycket motsvarar denna miljöpåverkan?

Utsläpp	Motsvarar
Växthuseffekt	13,9 km med en normalbil
Försurning	3 071,3 km med en normalbil
Övergödning	465,1 km med en normalbil
Vattenförbrukning	Ca 2 dagars vattenförbrukning i ett hushåll (4 personer)

Pesticider då?

Pesticiders miljöpåverkan på närmiljön är inte inkluderad i denna studie då valda miljöpåverkanskategorier ej tar hänsyn till toxicitet. Självklart är det viktigt att minimera pesticidanvändningen på golfbanor och många kommuner i Sverige kräver att golfbanor skall meddela sin pesticidanvändning samt hålla sig inom satta gränser.

Figure 23: The short document for communication. It is created from the web application.

The document for the golf clubs internal environmental work includes all the information as the short document, but also has additional information. Instead of only including the three impact categories global warming, eutrophication, acidification and the additional categories water and sand, the two final impact categories photochemical oxidation and ozone layer depletion are also included. The amount of resource use is displayed, both per functional unit and the total amount. The amount per functional unit is displayed since the result is calculated per functional unit and is the foundation for comparison between other golf courses. The total amount is also displayed since the user should not be forced to log in on the web application to see the total resource use and should easily compare the differences between two distinguished resource uses. The resource type is also displayed since it is included in the EPD format.

The long document also includes bar charts for all impact categories where the resources contribution to each impact is displayed. By having this presentation the reader will easily see which resources are contributing the most to the environmental impact and thus where a change would make the most difference. The amount of impact per resource is not displayed only the total aggregated value.

The document, as can be created from the website is displayed in Figure 24 to Figure 26.

Golfbanans miljöpåverkan
Forsgården GK
2011

Dokumentet är framtaget från www.golfbanansmiljopaverkan.se. Resultaten är baserade på en LCA studie som gjorts i examensarbetet "Environmental Assessment of a Golf Course". Resultaten är ungefärliga.

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Resultaten är presenterade per 18-håls golfrunda vilket är den funktionella enheten för studien.

Info om klubben

Antal banor: 9 + 18 hål
Antal medlemmar: 1500 st
Yta: 95 ha (2,2 ha green, 19 ha fairway)
Grässorter: Rödsvingel, vitgröe

Uppskattat antal 18-hålsrundor: 35000 st
varav registrerade 18-håls rundor i GIT: 24596 st
Uppskattat antal 9-hålsrundor: 10000 st

Snabb miljöfakta:

Forsgården GK har erhållit SGFs Miljödiplom, GGFs Miljöpris två ggr, SGAs Natur och Miljöpris, GEO-certifikat 2009 och 2010. Klubben använder grön el och källsorterar. Forsgården prioriterar leverantörer, som är certifierade enligt ISO 14001 och ISO 9001. Klubbens vision är att på sikt certifieras enligt ISO14025, type III Environmental Declarations.

Funktionell enhet

En 18-hålsgolfrunda. Funktionell enhet används för att kunna jämföra olika resultat, här är funktionen att spela golf och resultaten är därmed presenterade per 18-håls runda.

Resursanvändning

Kategori	Typ	Totalt mängd per år	Per 18-hålsrunda
Elektricitetsanvändning	Grön el	210440 kwh	5,3E0 kwh
Icke förnyelsebar energiresurs	Alkylat	2,5 kg	6,3E-5 kg
	Miljö diesel	18 kg	4,5E-4 kg
Vattenanvändning	Kommunalt vatten	764,5 m3	1,9E-2 m3
	Vatten från egen källa	35000 m3	8,8E-1 m3
Icke förnyelsebara material	Ogräsmedel	40 kg	1,0E-3 kg
	Gödningsmedel P	230 kg	5,8E-3 kg
	Gödningsmedel N	2132 kg	5,3E-2 kg
	Sand	1300 ton, 60 till leverantör	3,3E-2 ton
Förnyelsebara material	Kontorspapper	1078 kg	2,7E-2 kg

Figure 24:The long document for golf clubs internal work, created from the web application. Sheet 1 of 3.

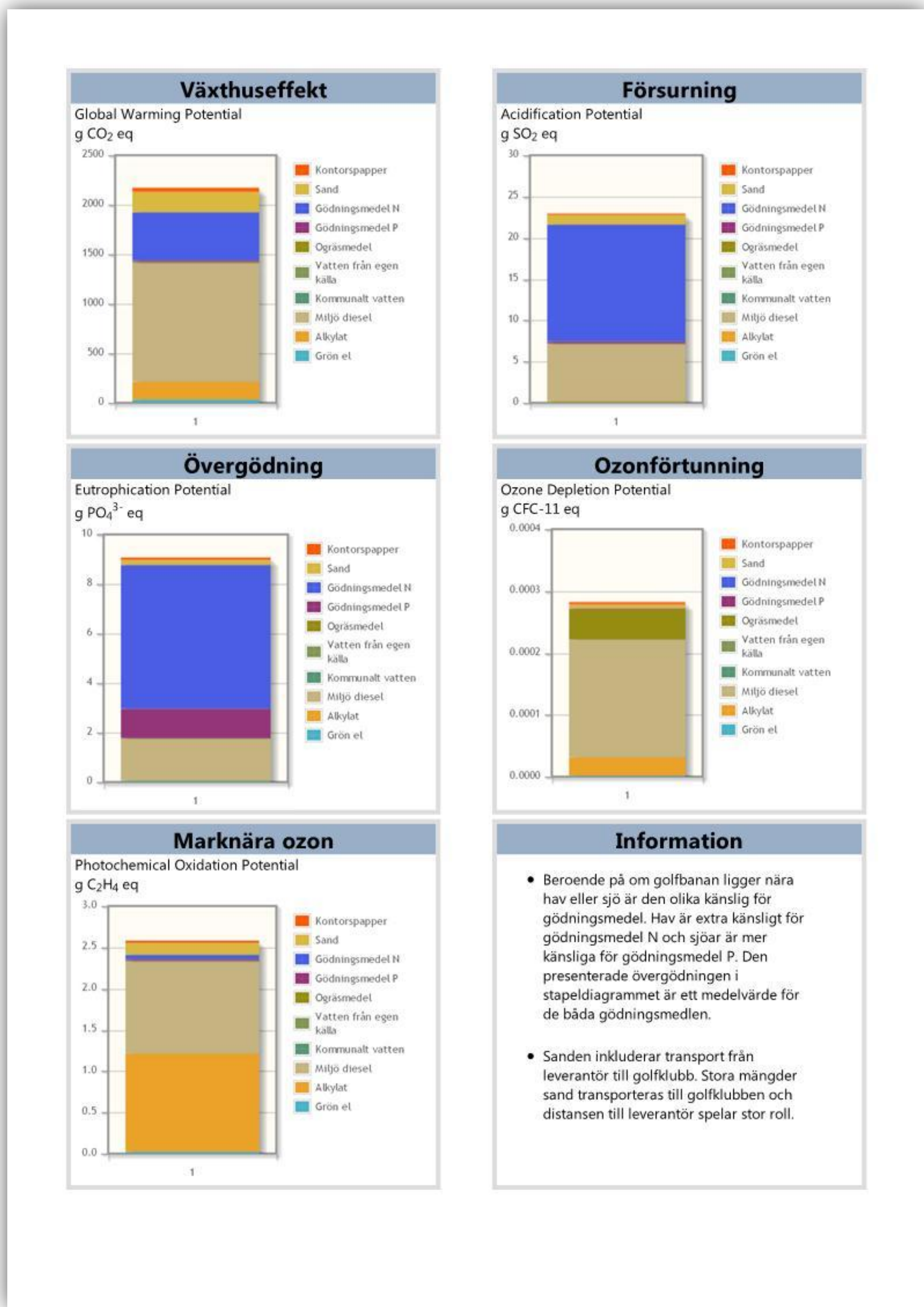

Figure 25: The long document for golf clubs internal work, created from the web application. Sheet 2 of 3.

En 18-håls golfrunda bidrar till följande miljöpåverkan

Växthuseffekt CO_2	Försurning SO_2	Övergödning PO_4^{3-}	Ozonförtunning CFC-11	Marknära ozon C_2H_4	Vatten Kommunalt / Egen källa	Sand
2 172 g	22,93 g	9,07 g	2,8E-4 g	2,58 g	19 *l* / 875 *l*	33kg

Hur mycket motsvarar denna miljöpåverkan?

Utsläpp	Motsvarar
Växthuseffekt	13,9 km med en normalbil
Försurning	3 071,3 km med en normalbil
Övergödning	465,1 km med en normalbil
Vattenförbrukning	Ca 2 dagars vattenförbrukning i ett hushåll (4 personer)

En km med normal bil ger

Växthuseffekt CO_2	Förurning SO_2	Övergödning PO_4^{3-}
156 g	0,007467 g	0,0195 g

Pesticider då?

Pesticiders miljöpåverkan på närmiljön är inte inkluderad i denna studie då valda miljöpåverkanskategorier ej tar hänsyn till toxicitet. Självklart är det viktigt att minimera pesticidanvändningen på golfbanor och många kommuner i Sverige kräver att golfbanor skall meddela sin pesticidanvändning samt hålla sig inom satta gränser.

Figure 26: The long document for golf clubs internal work, created from the web application. Sheet 3 of 3.

Since only the resources that were found to be hotspots are included in the application, the results in the web application compared to the results in the LCA studies performed in this report were not exactly alike. The differences in the total impacts are displayed in Table 12 and the differences in percentage are presented in Table 13.

Impact category	LCA studies			Web application		
	Forsgården GK	Best Case	Worst Case	Forsgården GK	Best Case	Worst Case
Global Warming	2.24	0.3	5.64	2.17	0.25	5.5
Acidification	0.023	0.0054	0.05	0.023	0.0052	0.05
Eutrophication	0.0092	0.0027	0.02	0.0091	0.0026	0.02
Photochemical oxidation	0.0027	0.00015	0.0057	0.0026	0.00008	0.0055
Ozone depletion	2.9E-07	1.2E-8	5.8E-7	2.8E-7	5.7E-9	5.7E-7

Table 12: The total amount of kg equivalents for all the impact categories from the three LCA studies and the web application.

Impact category	Forsgården GK	Best Case	Worst Case
Global Warming	3%	17%	2%
Acidification	0%	4%	0%
Eutrophication	1%	4%	0%
Photochemical oxidation	4%	47%	4%
Ozone depletion	3%	53%	2%

Table 13: The results of the web application compared with the results from the LCA studies. The differences are presented in percentage. Forsgården GK and Worst Case GK are not differing more than 4%. Best Case GK differs up to 53%.

As can be seen from Table 13 Forsgården GK and Worst Case GK are not differing more than 4% and are thus considered to have high enough accuracy. Best Case GK does however differ up to 53% due to that the distribution of impact between the resources in the LCA study for the impact categories photochemical oxidation and ozone depletion were more evenly distributed, and a lot of other resources, which did not become hotspots, did also have an impact, often over to the 1% limit.

8. Discussion and Conclusion

This section includes discussion and conclusions on the methodology, results and recommendations for future research.

8.1 Discussion and Conclusion on the Methodology Used

The choice of functional unit has affected the outcome of this report in many ways. Other functional units considered were a golf round, a year of maintenance etcetera.
If a round of golf would had been chosen instead of an 18-hole round of golf, it would mean that a golf club with a 9-hole golf course would have less impact per functional unit since the resource use is less. However since the function of going an 18- and a 9-hole round of golf is not equally valued an 18-hole round of golf was chosen as functional unit. Furthermore, to have a year of maintenance instead of an 18-hole golf round would result in that the function would be to maintain a golf course instead of to play golf and the amount of played rounds would not make any difference. It was decided that the function was to play golf and that the amount of played rounds should affect the outcome since a golf course that have few players does not have the same function and value to the public welfare.

To only have registered 18-hole rounds in GIT was also considered as a functional unit, since all other golf rounds are estimated. By only considering the total amount of registered rounds in GIT was found to be unfair for golf clubs which have both an 18 and 9-hole, which is a common case, since the 9-hole course would then have no function, but still contribute to the impact. But a consequence with estimated number of rounds is that the golf clubs have a possibility to tamper with the results in the application since more rounds leads to a lower impact per functional unit. The conclusion was that the user would enter the amount of registered golf rounds as well as the estimated number of rounds, which would give a more just result but also at the same time give the reader the opportunity to view the number of rounds critically.

The chosen delimitations affect the results. For example by not considering intangibles, potential environmental aspects may fall outside the study and create a wry picture of the golf courses environmental impact. Aspects such as creating an appealing milieu for frogs or birds are not considered. The focus is instead on the tangibles such as CO_2 emissions etcetera. Not considering the intangible values can give the wrong impression, that the intangibles are not as important as the tangibles, but they are both important.

Restaurants and golf shops are excluded from the study, but golf clubs are often seen as some kind of sports facility, and by not including restaurant and golf shop the whole facility is not considered. By excluding parts of the facility leads to allocation which results in uncertainties that could have been avoided. Also, a general round of golf often include lunch, so setting the system boundaries to what the green fee covers exclude some parts of the round of golf that many consider very important.

The construction of golf courses is not included. In LCA studies this is a common delimitation. But the construction of golf courses may be very harmful to the ecosystem depending on where it is built. If a golf boom would occur this is definitely an area that should be considered. But just looking at the management of the existing golf clubs the decision to exclude the construction is relevant.

Terrestrial CO_2 uptake has not been considered. Some parts of the golf course, such as the rough, can give a positive contribution, but that depends on what used to grow there before the construction of the golf course as well as how long it has existed. Replacing a primeval forest with rough results in a negative contribution while replacing a non-covered arable area results in a positive contribution by binding CO_2. The impact of decomposition of cut grass, which emits methane gas, and cutting down and growth of trees is therefore also not included, but has however an impact on the environment.

The final hotspots were based on the method chosen. However the choice that had the most influence on the result was the 1% limit. Whether or not 1% of the total impact was sufficient could be discussed, though if a resource had less than 1% it would mean that the other resources had a much larger impact and thus the resources which have less than 1% are not as critical. The 1% limit was determined to be legitimate and sufficient.

If other impact categories would have been chosen the result of this master's report could have been different. For example adding eco-toxicity as an impact category could have led to other inputs as final hotspots. It is also plausible that if other impact categories, such as scarcity, would have been included it would result in other resources as hotspots.

All data needed for the LCA of Forsgården GK has not been available. Instead of excluding the parts with missing data, assumptions were made. Excluding them could lead to a false impression of them being zero, however since that is not the case it is better making assumptions. There are still many uncertainties regarding these assumptions that have affected the results. The hotspots are certain because the size of them was very big compared to the other resources and they overshadowed the other resources. But assuming a golf course such as Best Case GK where the hotspots are barely hotspots other resources come forward and these resources are often very uncertain. For such a case the assumptions need to be considered once again and more carefully.

Best Case GK and Worst Case GK are based on the data for Forsgården GK, interviews with SGF representatives, interviews with municipalities and a literature study. By basing the actives and the magnitude of the inputs of Best Case GK and Worst Case GK on Forsgården GK it is assumed that Forsgården GK poses as a general, point-of-reference golf course. But the question is if Forsgården GK really is representative for other golf courses. There might be activities on other golf courses that have not emerged in the study and that therefore are not considered since these activities do not occur at Forsgården GK. The interviews with the SGF representatives and municipalities tried to cover the differences and deviations in golf course operation, but perhaps all the deviations weren't identified. The representatives from SGF are responsible for different geographical regions and might be partial towards their own region, also they might be partial towards golf and perceive golf's environmental performance to be higher than it is. The municipalities only register pesticide use, so even if the municipalities are more of a neutral source for information they do only have a fragment of the information needed. But by exaggerating the differences that were identified it is assumed that most of the golf clubs in Sweden are covered.

The tool is only based on the determined hotspots and thus the impact acquired from the web application is not the same as if a proper LCA study would have been performed. The purpose of the web application is however not to give the exact numbers of the impacts but more highlight the significant impacts and give an approximate picture of how the impacts are allocated between the resources. The documents generated from the application, used for communication and internal environmental work, include a section where the calculated amount of equivalents for the impact categories global warming, eutrophication and acidification are compared with the corresponding distance with a normal sized Swedish car. This comparison enables understanding of the environmental impact, which otherwise can be hard to understand. However, since the automotive industry has had hard legislation of emissions from combustion, the eutrophication and acidification impact of the car is relativity smaller which leads to a long distance when compared to a 18-hole round of golf. The other impact categories ozone layer depletion and photochemical oxidation were not included due to lack of information.

8.2 Discussion and Conclusion on the Results

Many resources that became hotspots were not directly connected to the management of the turf, for example the use of office paper. The electricity consumption resulted in one of the largest environmental impacts but was mainly used for operation of the facility, also not directly linked to the management of the turf. A lot of golf clubs seem to have the golf course operation very carefully monitored and controlled while electricity consumption and heating in buildings might have a lower prioritization. There seem to be potential for saving electricity at golf clubs, e.g. by changing heating system in buildings and introducing other electricity saving methods that in turn can decrease the environmental impacts.

Additionally, the LCA of Forsgården GK proved that a golf club is a complex facility, with activities not directly connected to golfing, such as restaurants and golf shop. Forsgården GK is situated quite central in Kungsbacka and is a popular lunch restaurant for non-golfers which adds to the complexity of the golf club and what should be included in the service golfing.

There were some unexpected hotspots, for example sand and the transportation of sand causes a big environmental impact. By choosing a local supplier the impact can be reduced. The quality of the sand is important for the golf clubs, therefore methods and ways to treat the sand in order to increase the quality is definitely of interest for the golf clubs. Sweden's vision is to decrease the use of natural sand, so finding ways to treat crushed products may become more and more important in the future.

The fossil fuels consumption is the resource contribution to the absolute highest environmental impacts, decreasing the fossil fuels consumption is of great importance for golf clubs. The choice of grass is a measure given more and more attention, there are different types of grass that grows slower and requires less management. Changing the type of grass can be the long term measure in reducing the fossil fuels consumption. Today, there exists hybrid mowers, in the future the fossil fuels consumption might not even be a problem if the machinery fleet is replaced by an electric fleet. But an electric fleet would then lead to new challenges.

The tool, if properly introduced, can ease the internal environmental work at golf clubs but also facilitate the communication of golf clubs' environmental performance to stakeholders. The expectation is that golf clubs with the help of the tool will be able to emphasize and highlight the resources contributing to the most significant environmental impacts and what they should focus their work on. The tool is also used for communicating golf clubs environmental performance to stakeholders, by comparing the golf clubs environmental impacts with driving a car a certain distance creates an understanding of what the impacts mean.

8.3 Discussion and Conclusion on Future Research

The focus of the study has been on management of the golf course however the environmental impact of the golfer was briefly touched. The screening indicated that the golfer's environmental impact posed a substantial part compared to the environmental impact of the golf course. A more elaborated study and information about the production of golf balls is needed to determine the full impact of the golfer in order to find ways of minimizing the golfer's impact and to give proper advice to golfers. To compare the environmental impacts of different types of golf balls is also of interest for further research. Such a study could result in a recommendation of which golf balls to choose in order to minimize the environmental impact.

It is also of interest to update the web application with an addition of the golfer's environmental impact. Having such a function can increase the environmental awareness among people and make them understand their contribution to the environmental impacts.

The determined hotspots are based on the current situation at Swedish golf clubs as well as the method chosen. When substantial improvements have been made at golf clubs Best Case GK is a possible future scenario. If such improvements are made the hotspots will change, small resources, previously overshadowed by the big ones, will appear and suddenly become hotspots. Therefore there is a need to update this study if substantial changes have been made in golf course management. Additionally, the possible hotspots which did not make the cut to become final hotspots are still considered to be possible hotspots and the recommendation for future research is to assess these resources more thoroughly.

This thesis is a first step towards EPD and of course a recommendation is to complete this quest. Certifying golf clubs according to the ISO 14025 can give an increased credibility regarding the golf clubs' environmental work, but also enable comparability between golf clubs. The expectation is that this thesis can pose as the foundation for a future PCR document.

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Appendix I

Forsgården GK	Global warming (GWP100)		Ozone layer depletion (ODP)		Photochemical oxidation		Acidification		Eutrophication	
	kg CO_2 eq	%	kg CFC-11 eq	%	kg C_2H_4 eq	%	kg SO_2 eq	%	kg PO_4^{3-} eq	%
Total	2.243066744		2.88921E-07		0.002651679		0.023207497		0.009191901	
Alkyd Paint	0.004702464	0.21%	1.06823E-09	0.37%	1.17355E-05	0.44%	2.8448E-05	0.12%	1.22077E-05	0.13%
Alkylate	0.180743303	8.06%	2.98678E-08	10.34%	0.001188416	44.82%	0.000194564	0.84%	4.2219E-05	0.46%
Cast Iron	0.012544434	0.56%	4.99783E-10	0.17%	9.96644E-06	0.38%	4.24724E-05	0.18%	2.61787E-05	0.28%
Oil and Air Filters	6.12838E-05	0.00%	5.70302E-12	0.00%	6.41578E-08	0.00%	2.79598E-07	0.00%	1.53259E-07	0.00%
Corrugated Board	0.010115492	0.45%	1.07506E-09	0.37%	9.71794E-06	0.37%	5.1221E-05	0.22%	2.80425E-05	0.31%
Detergents Mix	0.003346027	0.15%	3.47183E-10	0.12%	2.8253E-06	0.11%	2.35517E-05	0.10%	1.41621E-05	0.15%
Environmental Diesel	1.19616245	53.33%	1.90032E-07	65.77%	0.00111117	41.90%	0.006799595	29.30%	0.001656362	18.02%
Fertilizer K	0.01539776	0.69%	0	0.00%	3.8793E-06	0.15%	1.96684E-05	0.08%	3.63048E-06	0.04%
Fertilizer N	0.486073948	21.67%	0	0.00%	5.45936E-05	2.06%	0.014183957	61.12%	0.005811064	63.22%
Fertilizer P	0.015030532	0.67%	1.34886E-09	0.47%	1.79406E-05	0.68%	0.000219524	0.95%	0.001191837	12.97%
Fungicides	0.00031578	0.01%	9.19402E-11	0.03%	2.28293E-07	0.01%	1.36985E-06	0.01%	1.08604E-06	0.01%
Golf Balls	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Golf Pegs	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Grass Seeds	0.005075799	0.23%	4.21264E-10	0.15%	3.139E-06	0.12%	2.54694E-05	0.11%	1.42273E-05	0.15%
Green Electricity	0.033681173	1.50%	1.57473E-09	0.55%	2.37037E-05	0.89%	9.90681E-05	0.43%	4.85662E-05	0.53%
Herbicides	0.010208926	0.46%	4.916E-08	17.02%	1.0648E-05	0.40%	0.000107342	0.46%	2.74412E-05	0.30%
Hydralic Hoses	0.001543897	0.07%	0	0.00%	1.58177E-06	0.06%	6.90135E-06	0.03%	4.05937E-07	0.00%
Iron Sulphate	0.001251111	0.06%	7.43521E-11	0.03%	5.6412E-07	0.02%	5.70811E-06	0.02%	4.92322E-06	0.05%
Motor Oil	0.00207522	0.09%	1.71748E-09	0.59%	7.53441E-06	0.28%	1.56331E-05	0.07%	2.92593E-06	0.03%
Lubricant Oil	0.00012813	0.01%	1.32386E-10	0.05%	3.28074E-07	0.01%	1.68695E-06	0.01%	4.0143E-08	0.00%
Office Paper	0.039641867	1.77%	3.84578E-09	1.33%	2.77962E-05	1.05%	0.000178457	0.77%	8.85447E-05	0.96%
Water Dam	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Sand	0.207798138	9.26%	5.99951E-09	2.08%	0.000142136	5.36%	0.001148935	4.95%	0.000204988	2.23%
Tires	0.010329296	0.46%	1.29648E-09	0.45%	9.90198E-06	0.37%	3.80858E-05	0.16%	6.80735E-06	0.07%
Water Municipality	0.004666386	0.21%	1.72887E-10	0.06%	9.87618E-07	0.04%	4.31177E-06	0.02%	8.35714E-07	0.01%
Wood	0.002173328	0.10%	1.89134E-10	0.07%	1.28205E-05	0.48%	1.12484E-05	0.05%	5.25312E-06	0.06%

Table 14: The environmental impact of Forsgården GK per functional unit.

Best Case GK	Global warming (GWP100)		Ozone layer depletion (ODP)		Photochemical oxidation		Acidification		Eutrophication	
	kg CO_2 eq	%	kg CFC-11 eq	%	kg C_2H_4 eq	%	kg SO_2 eq	%	kg PO_4^{3-} eq	%
Total	0.298271204		1.15468E-08		0.000146884		0.0054176		0.002709857	
Alkyd Paint	0.004702464	1.58%	1.06823E-09	9.25%	1.17355E-05	7.99%	2.8448E-05	0.53%	1.22077E-05	0.45%
Cast Iron	0.006291053	2.11%	2.50642E-10	2.17%	4.99818E-06	3.40%	2.13E-05	0.39%	1.31287E-05	0.48%
Corrugated Board	0.014161689	4.75%	1.50508E-09	13.03%	1.36051E-05	9.26%	7.17094E-05	1.32%	3.92595E-05	1.45%
Detergents Mix	0.001673013	0.56%	1.73591E-10	1.50%	1.41265E-06	0.96%	1.17759E-05	0.22%	7.08104E-06	0.26%
Fertilizer K	0.005139252	1.72%	0	0.00%	1.29478E-06	0.88%	6.56465E-06	0.12%	1.21173E-06	0.04%
Fertilizer N	0.161872656	54.27%	0	0.00%	1.81808E-05	12.38%	0.00472355	87.19%	0.001935204	71.41%
Fertilizer P	0.007188515	2.41%	6.45106E-10	5.59%	8.58029E-06	5.84%	0.00010499	1.94%	0.000570009	21.03%
Golf Balls	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Golf Pegs	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Grass Seeds	0.002537899	0.85%	2.10632E-10	1.82%	1.5695E-06	1.07%	1.27347E-05	0.24%	7.11363E-06	0.26%
Green Electricity	0.024683095	8.28%	1.15404E-09	9.99%	1.73711E-05	11.83%	7.26016E-05	1.34%	3.55915E-05	1.31%
Hydralic Hoses	0.001543897	0.52%	0	0.00%	1.58177E-06	1.08%	6.90135E-06	0.13%	4.05937E-07	0.01%
Iron Sulphate	0.000625556	0.21%	3.71761E-11	0.32%	2.8206E-07	0.19%	2.85405E-06	0.05%	2.46161E-06	0.09%
Lubricant Oil	0.00012813	0.04%	1.32386E-10	1.15%	3.28074E-07	0.22%	1.68695E-06	0.03%	4.0143E-08	0.00%
Motor Oil	0.001242209	0.42%	1.02807E-09	8.90%	4.51004E-06	3.07%	9.35784E-06	0.17%	1.75144E-06	0.06%
Office Paper	0.019820934	6.65%	1.92289E-09	16.65%	1.38981E-05	9.46%	8.92284E-05	1.65%	4.42723E-05	1.63%
Oil and Air Filters	6.12838E-05	0.02%	5.70302E-12	0.05%	6.41578E-08	0.04%	2.79598E-07	0.01%	1.53259E-07	0.01%
Sand	0.031045014	10.41%	1.81461E-09	15.72%	2.41031E-05	16.41%	0.000201463	3.72%	2.73586E-05	1.01%
Tires	0.010329296	3.46%	1.29648E-09	11.23%	9.90198E-06	6.74%	3.80858E-05	0.70%	6.80735E-06	0.25%
Water Dam	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Water Municipality	0.00305192	1.02%	1.13072E-10	0.98%	6.45924E-07	0.44%	2.81999E-06	0.05%	5.46575E-07	0.02%
Wood	0.002173328	0.73%	1.89134E-10	1.64%	1.28205E-05	8.73%	1.12484E-05	0.21%	5.25312E-06	0.19%

Table 15: The environmental impact of Best Case GK per functional unit.

Worst Case GK	Global warming (GWP100)		Ozone layer depletion (ODP)		Photochemical oxidation		Acidification		Eutrophication	
	kg CO_2 eq	%	kg CFC-11 eq	%	kg C_2H_4 eq	%	kg SO_2 eq	%	kg PO_4^{3-} eq	%
Total	5.643335658		5.82166E-07		0.005677616		0.050414647		0.020374441	
Alkyd Paint	0.004702464	0.08%	1.06823E-09	0.18%	1.17355E-05	0.21%	2.8448E-05	0.06%	1.22077E-05	0.06%
Alkylate	0.361486605	6.41%	5.97357E-08	10.26%	0.002376833	41.86%	0.000389127	0.77%	8.44381E-05	0.41%
Cast Iron	0.025088869	0.44%	9.99566E-10	0.17%	1.99329E-05	0.35%	8.49447E-05	0.17%	5.23574E-05	0.26%
Corrugated Board	0.014161689	0.25%	1.50508E-09	0.26%	1.36051E-05	0.24%	7.17094E-05	0.14%	3.92595E-05	0.19%
Detergents Mix	0.007645672	0.14%	7.93312E-10	0.14%	6.45582E-06	0.11%	5.38157E-05	0.11%	3.23604E-05	0.16%
Electricity	0.425111862	7.53%	2.66273E-08	4.57%	0.00023315	4.11%	0.001653155	3.28%	0.000524287	2.57%
Environmental Diesel	1.661336737	29.44%	2.63934E-07	45.34%	0.001543292	27.18%	0.009443882	18.73%	0.002300502	11.29%
Fertilizer K	0.030795519	0.55%	0	0.00%	7.75861E-06	0.14%	3.93368E-05	0.08%	7.26096E-06	0.04%
Fertilizer N	0.972147896	17.23%	0	0.00%	0.000109187	1.92%	0.028367914	56.27%	0.011622128	57.04%
Fertilizer P	0.043131092	0.76%	3.87063E-09	0.66%	5.14818E-05	0.91%	0.000629938	1.25%	0.003420054	16.79%
Fungicides	0.00126312	0.02%	3.67761E-10	0.06%	9.13171E-07	0.02%	5.47941E-06	0.01%	4.34416E-06	0.02%
Golf Balls	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Golf Pegs	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Grass Seeds	0.010151597	0.18%	8.42528E-10	0.14%	6.27799E-06	0.11%	5.09387E-05	0.10%	2.84545E-05	0.14%
Herbicides	0.040835702	0.72%	1.9664E-07	33.78%	4.25919E-05	0.75%	0.000429367	0.85%	0.000109765	0.54%
Hydralic Hoses	0.001543897	0.03%	0	0.00%	1.58177E-06	0.03%	6.90135E-06	0.01%	4.05937E-07	0.00%
Iron Sulphate	0.003753334	0.07%	2.23056E-10	0.04%	1.69236E-06	0.03%	1.71243E-05	0.03%	1.47697E-05	0.07%
Lubricant Oil	0.00012813	0.00%	1.32386E-10	0.02%	3.28074E-07	0.01%	1.68695E-06	0.00%	4.0143E-08	0.00%
Motor Oil	0.00207522	0.04%	1.71748E-09	0.30%	7.53441E-06	0.13%	1.56331E-05	0.03%	2.92593E-06	0.01%
Office Paper	0.055498614	0.98%	5.38409E-09	0.92%	3.89147E-05	0.69%	0.00024984	0.50%	0.000123963	0.61%
Oil and Air Filters	6.12838E-05	0.00%	5.70302E-12	0.00%	6.41578E-08	0.00%	2.79598E-07	0.00%	1.53259E-07	0.00%
Sand	1.806290243	32.01%	8.41782E-09	1.45%	0.001098941	19.36%	0.008567327	16.99%	0.001937432	9.51%
Tires	0.041317183	0.73%	5.18592E-09	0.89%	3.96079E-05	0.70%	0.000152343	0.30%	2.72294E-05	0.13%
Water Dam	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Water Municipality	0.1220768	2.16%	4.52288E-09	0.78%	2.5837E-05	0.46%	0.0001128	0.22%	2.1863E-05	0.11%
Winter Cover	0.0105588	0.19%	3.62022E-12	0.00%	2.70798E-05	0.48%	3.14082E-05	0.06%	2.98683E-06	0.01%
Wood	0.002173328	0.04%	1.89134E-10	0.03%	1.28205E-05	0.23%	1.12484E-05	0.02%	5.25312E-06	0.03%

Table 16: The environmental impact of Worst Case GK per functional unit.

Appendix II

Calculations of amount of electricity needed for replacing fossil fuels.

Assumed efficiencies:
η_{mowers} = 22 %
$\eta_{electric\ engines}$ = 90 %

Volume:
$V_{env.\ diesel}$ = 18 000 litres
$V_{alkylate}$ = 2 500 litres

Energy density (Biogasportalen, n.d.):
$E_{env.\ diesel}$ = 9,8 kWh
$E_{alkylate}$ = 9,06 kWh

$$Electr.energy\ needed = \frac{\left((V_{env.diesel} \times E_{env.diesel}) + (V_{alkylate} \times E_{alkylate})\right) \times \eta_{mowers}}{\eta_{electric\ engines}} = \frac{\left((18000 \times 9.8) + (2500 \times 9.06)\right) \times 0,22}{0,90} = 48656.66 \approx 49000kWh$$

Appendix III

Forsgården GK's machinery fleet

Brand	Model	Amount
Jacobsen (green)	GK6	2
Jacobsen (tee/foregreen)	GK6	2
Jacobsen (fairway)	LF 3400	1
Jacobsen (fairway)	LF 3800	1
John Deere (fairway)	7500	1
Jacobsen (green areas)	TR3	1
John Deere (green)	7200	1
Jacobsen (semi-rough)	AR522	1
Jacobsen (rough)	HR5111	2
John Deere (bunker rake)	1200 A	2
Tru-Turf (roller)	RS48-11C	2
John Deere	5720	1
John Deere (mini tractor)	4200	1
Iseki (mini tractor)	TX2140	1
Cushman truck	Truckster	2
Ez-Go (transport vehicle)	WH 350	5
John Deere (transport vehicle)	Gator	1
Flexotronic	Electric car	2
Mitsubishi (pickup)	L200	1
Turfco (green dresser)	SP 1530	1
Turfco (green dresser)	Falldressare	1
Bredal (fw dresser)	Turfdress	1
John Deere (areator)	Aercore 150	1
Parkland (fw scarifier)	VF250	1
Tractor trolley	Möre 41K	1
Stilh (brush saw)	S 480	8
Stilh (leaf blower)	BR 600	2
Stilh (chainsaw)	R 350	2

Appendix IV

Interviews with the SGF’s agronomists.

Name	Geographical Region
Göran Hansson	Skåne and some parts of Halland
Mikael Frisk	Småland, Blekinge, Öland, Örebro, Värmland
Kim Sintorn	Halland and some parts of Göteborg
Peter Edman	Västra Götaland, Bohuslän and some parts of Göteborg
Carl-Johan Lönnberg	Södermanland, Östergötland, Stockholm, Gotland
Thomas Andersson	Uppland, Västmanland, Dalarna Gävleborg
Boel Sandström	Hälsingland, Jämtland-Härjedalen, Medelpad, Ångermanland, Västerbotten, Norrbotten

Appendix V

Resources and Corresponding Names in SimaPro

All resources in the three LCA studies are assumed to correspond to the same resources in SimaPro. The resources assumed are presented in the table.

Resource	Corresponding to resource in SimaPro
Alkylate	Petrol, low-sulphur, at refinery
Anti-rust Agent	Alkyd paint, white, 60% in solvent, at plant
Cast Iron	Cast iron, at plant/RER S
Corrugated Board	Corrugated board base paper, kraftliner, at plant
Course Marks	Sawn timber, softwood, planed, air dried, at plant
Detergent Mix	Detergent mix (5% MAC 54AB and 95% water) 1 kg of MAC 54AB: 1% Ethoxylated alcohols, unspecified, at plant/RER S 1% Esterquat, tallow, at plant/RER S 1% Alkylbenzene sulfonate, linear, petrochemical, at plant/RER S 10% Layered sodium silicate, SKS-6, powder, at plant/RER S 5% Phosphoric acid, industrial grade, 85% in H2O, at plant/RER S 82% Tap water, at user/CH S
Enamel paint	Alkyd paint, white, 60% in solvent, at plant
Electricity	Electricity, high voltage, production SE, at grid/SE S
Environmental Diesel	Diesel, low-sulphur, at regional storage
Fertilizer K	Fertiliser (K)
Fertilizer N	Fertiliser (N)
Fertilizer P	Single superphosphate, as P2O5, at regional storehouse
Fungicides	Fungicides, at regional storehouse
Golf Balls	1 kg of Golf Balls: 5 litres Diesel, combusted in industrial boiler 1 kg High impact polystyrene (HIPS) E

Golf Pegs	1 kg of Golf Pegs: 75% Sawn lumber, softwood, rough, green, at sawmill, INW/kg/RNA 25% Polypropylene resin E
Grass Seeds	Grass seed IP, at regional storehouse
Green Electricity Mix	1 kWh of Green Electricity Mix: 90% Electricity, hydropower, at power plant 10% Electricity, at wind power plant
Herbicides	Herbicides, at regional storehouse
Hydraulic Hoses	Polybutadiene E
Iron Sulphate	Iron sulphate, at plant
Lubricants	Lubricant oil (1)
Motor Oil	Light fuel oil, at regional storage
Office Paper	Paper, wood-containing, LWC, at regional storage
Oil and Air Filters	Core board, at plant
Sand	Transport and Sand used: Lorry transport, Euro 0, 1, 2, 3, 4 mix, 22 t total weight, 17,3t max payload Sand 0/2, wet and dry quarry, production mix, at plant, undried
Tires	1 piece of Tire: 1.05 kg Synthetic rubber, at plant/RER S 1.05 kg Polybutadiene E 0.6 kg Stainless steel hot rolled coil, annealed & pickled, elec. arc furnace route, prod. mix, grade 304 RER S 0.6 kg Silica sand, at plant/DE S 0.6 kg Carbon black, at plant/GLO S 0.25 kg Polyester resin, unsaturated, at plant/RER S 0.4 kg Benzene E
Water, Dam	Rain Water
Water, Municipality	Water (Tap)
Winter Cover	Polyethylene, HDPE, granulate, at plant/RER S
Wood paint	Alkyd paint, white, 60% in solvent, at plant

Resources and Corresponding Emissions

Environmental Diesel: Forsgården GK uses Swedish Environmental Diesel (MK1). The production of environmental diesel is assumed to be more energy intensive than regular diesel. In SimaPro the resource called “Diesel, low-sulphur, at regional storage” includes the production of diesel. For production of 1 kg of environmental diesel 1.05 kg of regular diesel (Diesel, low-sulphur, at regional storage) is assumed to be needed. The Swedish Environmental Diesel is combusted without catalyst. The emissions from combustion of environmental diesel without catalyst are not included in SimaPro. These emissions are assumed to be airborne, the sort and the amount of the emissions assumed are listed below (Westerholm et. al., 2001).

Environmental Diesel (MK1), no catalyst			
Inputs from technosphere	Diesel, low-sulphur, at regional storage/CH S	1.05	kg
Emissions to air	Nitrogen oxides	0.028897243	kg
	Carbon dioxide	2.664160401	kg
	Carbon monoxide	0.015087719	kg
	Hydrocarbons, unspecified	0.000927318	kg
	Soot	0.000749373	kg

Alkylate: The production of alkylate is assumed to be the same as for petrol. In SimaPro the production of “Petrol, low-sulphur, at refinery” is assumed to correspond to the production of alkylate. The alkylate is combusted without catalyst, the assumed emissions are listed below (Christensen, Westerholm and Almén, 2001).

Alkylate			
Inputs from technosphere	Petrol, low-sulphur, at refinery/CH S	1	kg
Emissions to air			
	Nitrogen oxides	0.002721088	kg
	Carbon dioxide	1.771714405	kg
	Carbon monoxide	0.76462585	kg
	Soot	0.001088435	kg
	Methane	0.005238095	kg
	Ethane	0.003687075	kg
	Ethanol	0.002217687	kg
	Nitrogen monoxide	0.000612245	kg
	Pyrene	0.000146939	kg
	Cyclopentane	0.000164626	kg
	Hydrocarbons, aromatic	0.03537415	kg
	Benzo(ghi)perylene	8.61224E-05	kg
	Benzo(e)pyrene	6.13605E-05	kg
	Indeno(1,2,3-cd)pyrene	3.90476E-05	kg
	Fluorenone	8.68027E-05	kg
	Benz[a]anthracene,12-methyl-	2.93878E-05	kg
	Benzo(g,h,i)fluoranthene	2.84354E-05	kg

Detergent mix: The detergent used is MAC 54AB. The detergent mix consists of 5% MAC 54AB and 95% water according to a mechanic at Forsgården GK. The inputs in SimaPro are based on the Safety Datasheet on the MAC series (Eriksson, 2010). No emissions are assumed since the detergent mix passes an oil separator before returned to the hydrologic cycle.

Detergent			
Inputs from technosphere	Ethoxylated alcohols, unspecified, at plant/RER S	0.01	kg
	Esterquat, tallow, at plant/RER S	0.01	kg
	Alkylbenzene sulfonate, linear, petrochemical, at plant/RER S	0.01	kg
	Layered sodium silicate, SKS-6, powder, at plant/RER S	0.1	kg
	Phosphoric acid, industrial grade, 85% in H2O, at plant/RER S	0.05	kg
	Tap water, at user/CH S	0.82	kg

Fertilizer N: The production of nitrogen fertilizer is assumed to be the same as for "Fertiliser (N)" in SimaPro. The emissions from the nitrogen fertilizer is assumed to be both air- and water-borne, the assumed allocation is listed below (Hansson et.al, 1986).

Fertilizer N			
Inputs from technosphere	Fertiliser (N)	1	kg
Emissions to air	Ammonia	0.15	kg
Emissions to water	Nitrogen, organic bound	0.15	kg
	Ammonium, ion	0.15	kg

Fertilizer P: The production of phosphorus fertilizer is assumed to be the same as for "Single superphosphate, as P2O5, at regional storehouse" in SimaPro. The emissions from the phosphorus fertilizer is assumed to be both water- and soil-borne, the assumed allocation is listed below (Ivarsson and Brink, 1986).

Fertilizer P			
Inputs from technosphere	Single superphosphate, as P2O5, at regional storehouse/RER S	1	kg
Emissions to water	Phosphoric acid	0.15	kg
Emissions to soil	Phosphate	0.05	kg

Fertilizer K: The production of potassium fertilizer is assumed to be the same as for "Fertiliser (K)" in SimaPro. The emissions from the potassium fertilizer are assumed to be air-, water- and soil-borne, the assumed allocation is listed below (Ivarsson and Brink, 1986).

Fertilizer K			
Inputs from technosphere	Fertiliser (K)	1	kg
Emissions to air	Potassium	0.05	kg
Emissions to water	Potassium	0.05	kg
Emissions to soil	Potassium	0.05	kg

Fungicides: Forsgården GK uses two kind of fungicides, Baycore and Amistar, the production of them is assumed to be the same as for “Fungicides, at regional storehouse” in SimaPro. The emissions from the fungicides are assumed to be water-borne and the assumed emissions are based on the inputs in SimaPro for “Fungicides, at regional storehouse” where all inputs are assumed to become emissions. The assumed emissions are listed below.

Fungicides			
Inputs from technosphere	Fungicides, at regional storehouse/RER S	1	kg
Emissions to water	Trichlorophenol	0.04	kg
	Bromine	0.36923	kg
	Iodine-129	0.030086	kBq
	Dichlorophenol	0.05832	kg
	Chlorendic acid	0.1204	kg
	Sodium hydroxide	0.41749	kg
	Toluene	0.11685	kg
	Ethylene glycol	0.03	kg
	Cadmium	5.859E-07	kg
	Aluminium	0.0085992	kg
	Chromium	0.003672	kg
	Cobalt	1.8176E-06	kg
	Lead	0.000053453	kg
	Sulfur	0.0076125	kg
	Uranium-238	0.00055955	kBq
	Zinc	0.010891	kg
	Thorium	0.0054133	kg
	Chloride	0.49592	kg

Herbicides: Forsgården GK uses a herbicide called Spitfire, the production of the herbicide is assumed to be the same as for "Herbicides, at regional storehouse" in SimaPro. The emissions from the herbicides are assumed to be water-borne and the assumed emissions are based on the inputs in SimaPro for "Herbicides, at regional storehouse" where all inputs are assumed to become emissions. The assumed emissions are listed below.

Herbicides			
Inputs from technosphere	Herbicides, at regional storehouse/RER S	1	kg
Emissions to water	Bromine	0.068461	kg
	Iodine-129	0.035586	kBq
	Bromide	0.051519	kg
	Chloride	0.86358	kg
	Ethylene oxide	0.00015834	kg
	Fluoride	0.0024529	kg
	Formaldehyde	0.00013509	kg
	Phenol	0.003447	kg
	Potassium, ion	0.0071221	kg
	Sodium 4-(2H-naphtho(1,2-d)triazol-2-yl)stilbene-2-sulfonate	0.53443	kg
	Sulfate	0.069385	kg
	Acetic anhydride	0.094827	kg

Iron Sulphate: The iron sulphate is assumed to med water-borne and 90% is assumed to leak in the form of iron ions.

Iron Sulphate			
Inputs from technosphere	Iron sulphate, at plant/RER S	1	kg
Emissions to water	Iron, ion	0.9	kg

Golf Balls: Some golf balls are never found and therefore left behind on the golf course to decompose. On Forsgården GK 1 golf ball/round is assumed to be lost. An assumption is that Forsgården GK has 40 000 rounds/year which gives a total of 40 000 lost golf balls/year. Emissions are assumed to be water-borne and are listed below (Kastrup Petersen and Riger Kusk, 2009). The production of golf balls is not included, since it is the golfer buys and consumes golf balls and is thus responsible for the environmental impact of the production.

Golf Balls			
Emissions to water	Lead	23	mg
	Cadmium	3.5	mg
	Copper	64	mg
	Zinc	91 000	mg
	Chromium	1.2	mg
	Nickel	3.3	mg
	Hydrocarbons, aliphatic, alkanes, unspecified	4 900	mg

Golf Pegs: 75% of the number of pegs are assumed to be made of wood and 25% of poly propylene, only the pegs that are made of poly propylene are assumed to have emissions.

Golf Pegs			
Emissions to soil	1 kg golf pegs: Zinc	61	mg

Appendix VI

Assumptions regarding Amount of Resources

Resource	Assumptions for Forsgården GK	Assumptions for Best Case GK	Assumptions for Worst Case GK
Alkylate	Amount given by Forsgården GK.	No alkylate consumption. All vehicles are assumed to be electric.	Twice as much as Forsgården GK is assumed, which gives a total of 5 m^3. The assumed density for alkylate is 0.75 kg/l
Anti-rust Agent	Anti-rust agent is assumed to be used for maintenance of the vehicles and equipment. 1 kg/vehicle and year is assumed to be used which gives a total of 32 kg.	The same as for Forsgården GK is assumed.	The same as for Forsgården GK is assumed.
Cast Iron	Forsgården GK reported that they had 1000 kg of scrap metal for a period of three years. A mean value of these three years was calculated, 333 kg/year. An assumption is made that an equal amount enters Forsgården GK every year.	1 machine has 1 knife cylinder, á 5 kg, that is replaced once a year. 11 machines have 4 bedknifes, á 1 kg, that are replaced once a year. 11 machines have 1 roll, á 2 kg, that are changed 2 times/year. 1 machine has 1 coring tine module, á 2 kg, that is replaces 2 times/year. Totally 97 kg of cast iron is assumed to be replaced every year.	The consumption is assumed to be twice as big as for Forsgården GK.
Corrugated Board	Forsgården GK reported that they have 616 kg of corrugated board waste. Therefore an assumption is made that an equal amount enters Forsgården GK.	Half of Forsgården GK's corrugated board consumption is assumed to be used.	The corrugated board consumption is assumed to be 40% higher than for Forsgården GK.
Course Marks	1 m^3 wood is assumed to be needed for the sticks for marking the golf course at Forsgården GK.	The same number of sticks as for Forsgården GK is assumed to be used.	The same number of sticks as for Forsgården GK is assumed to be used.
Detergent Mix	One wash is assumed to consume 20 kg detergent mix (Helgesson, n.d.). Forsgården GK's active playing season is assumed to be 30 weeks. Forsgården GK have 2 green clippers assumed to be washed 4 times/week and 6 other clippers assumed to be	The gaming season is assumed to be 30 weeks, 2 green clippers are assumed to be washed 2 times/week and 6 other clippers 0.5 times/week.	The gaming season is also assumed to be 30 weeks, 2 green clippers are assumed to be washed 4 times/week and 6 other clippers 1 time/week.

	washed 1 time/week. This altogether is 914 kg of detergent mix per year.		
Electricity	Green electricity is used.	Green electricity is used.	Swedish Electricity mix is assumed to be used and the electricity consumption is assumed to be double consumption at Forsgården GK.
Enamel Paint	Enamel paint is assumed to be used for maintenance of the vehicles and equipment. 1 kg/vehicle and year is assumed to be used which gives a total of 32 kg.	The same as for Forsgården GK is assumed.	The same as for Forsgården GK is assumed.
Environmental Diesel	Amount given by Forsgården GK.	No environmental diesel consumption. All vehicles are assumed to be electric.	Another 7 m^3 besides Forsgården GK's consumption, which gives a total of 25 m^3. The assumed density for environmental diesel is 0.8 kg/l
Fertilizer K	Amount given by Forsgården GK.	One third of Forsgården GK's consumption is assumed.	Twice as much as Forsgården GK is assumed to be used.
Fertilizer N	Amount given by Forsgården GK.	One third of Forsgården GK's consumption is assumed.	Twice as much as Forsgården GK is assumed to be used.
Fertilizer P	Amount given by Forsgården GK.	One third of Forsgården GK's consumption is assumed.	Twice as much as Forsgården GK is assumed to be used.
Fungicides	Forsgården GK uses two kind of fungicides, Baycore and Amistar.	No fungicides are assumed to be used.	Four times as much as Forsgården GK is assumed to be used.
Golf Balls	1 golf ball/round is assumed to be lost. An assumption is that Forsgården GK has 40 000 rounds/year which gives a total of 40 000 lost golf balls/year.	1 golf ball/round is assumed to be left behind on the golf course.	3 golf balls/round are assumed to be left behind on the golf course.
Golf Pegs	2 pegs/round are assumed to be left behind on the golf course. An assumption is that Forsgården GK has 40 000 rounds/year which gives a total of 80 000 lost pegs/year.	The same as for Forsgården GK is assumed.	The same as for Forsgården GK is assumed.
Grass Seeds	Grass seeds are for reseeding and Forsgården GK is assumed to reseed 1 ha/year. According to an interview with an SGF agronomist 100 kg grass seeds/ha is needed for reseeding which for	Half of Forsgården GK's grass seed consumption is assumed to be used.	The grass seed consumption is assumed to be twice as high as for Forsgården GK.

	Forsgården's case gives a total of 100 kg.		
Green Electricity	The electricity mix used on Forsgården GK comes from Telge Energi and is a mix of 90% hydropower and 10% wind power.	Same electricity mix as for Forsgården GK. All vehicles are assumed to be electric, the energy from environmental diesel and alkylate has been calculated into electric energy. The energy needed for the electric vehicles is 49 000 kWh (see appendix II for calculations). The ordinary electricity consumption has been reduced compared to Forsgården GK's consumption of 330 840 kWh to instead 160 000 kWh. The total electricity consumption for Best Case GK is 209 000 kWh.	No green electricity is used.
Herbicides	Forsgården GK uses a herbicide called Spitfire**.**	No herbicides are assumed to be used.	Four times as much as Forsgården GK is assumed to be used.
Hydraulic Hoses	Hydraulic hoses are replaced on all the 32 vehicles at Forsgården GK once a year. One hose is assumed to weigh 0.5 kg and be made of polybutadiene.	The same number of hydraulic hoses as for Forsgården GK is replaced. They are assumed to weigh 0.5 kg/piece, in total 16 kg.	The same number of hydraulic hoses as for Forsgården GK is replaced. They are assumed to weigh 0.5 kg/piece, in total 16 kg.
Iron Sulphate	Amount given by Forsgården GK.	Half of Forsgården GK's iron sulphate consumption is assumed to be used.	The iron sulphate consumption is assumed to be three times higher than for Forsgården GK.
Lubricants	Forsgården uses lubricants for maintenance of the vehicles and equipment. According to an interview a mechanic at Forsgården GK 8 litres/year is used.	The same as for Forsgården GK is assumed.	The same as for Forsgården GK is assumed.
Motor Oil	Forsgården GK reported that they have 142 kg of oil waste. Therefore an assumption is made that an equal amount enters Forsgården GK.	The consumption of motor oil is assumed to be the same as for Forsgården GK with a total amount of 142 kg.	The consumption of motor oil is assumed to be the same as for Forsgården GK with a total amount of 142 kg.
Office Paper	Forsgården GK reported that they have 1078 kg of office paper waste. Therefore an assumption is made that an equal amount enters Forsgården GK.	Half of Forsgården GK's office paper consumption is assumed to be used.	40% more than for Forsgården GK is assumed to be used.

Oil and Air Filters	All vehicles at Forsgården GK are assumed to change their oil and air filters once a year. Both the oil and air filters are assumed to be made of core board. Totally 64 filters are changed a year and one filter is assumed to weigh 0,078 kg/piece.	The number of oil and air filters used is assumed to be the same as for Forsgården GK.	The number of oil and air filters used is assumed to be the same as for Forsgården GK.
Sand	The amount of sand and the supplier was given by Forsgården GK. A total of 1 300 tons sand was used and the distance is 60 km one way from Lysegården Sand & Trä AB.	400 tons of sand is assumed to be used. The sand is assumed to be transported from a local producer with a distance of 10 km one way.	1 500 tons of sand is assumed to be used. The sand is assumed to be transported 700 km one way, for example from Jönköping to Sundsvall.
Tires	Forsgården GK have 32 vehicles and 1 tire/vehicle is assumed to be changed once a year, in total, 32 tires per year.	1 tire/vehicle is assumed to be changed once a year, and the total number of vehicles is assumed to be the same as for Forsgården GK which gives a total of 32 tires per year.	All 4 tires are assumed to be changed on all the vehicles and the total number of vehicles is also 32 which give a total of 128 tires per year.
Water, Dam	Amount given by Forsgården GK.	The same water consumption as Forsgården GK.	Worst Case GK has lower water consumption from their dam than Forsgården since they also use municipal water for irrigation. 20 000 m^3 is assumed to be used.
Water, Municipality	Amount given by Forsgården GK.	Decreased with about 300 m^3 compared to Forsgården GK.	Some of the municipal water is assumed to be used for irrigation of the golf course. 20 000 m^3 is assumed to be used.
Winter Cover	No winter cover is used.	No winter cover is used.	1 ha covered is assumed to be covered, 22 g polyethylene/m^2 is assumed to be used.
Wood paint	Wood paint is used for painting the sticks for marking. The total painted area is assumed to be 20 m^2 and 10 m^2 is assumed to need 1 litre of paint with an assumed density of 1 kg/litre which in total is 2 kg for painting the sticks for marking at Forsgården GK.	The same as for Forsgården GK is assumed.	The same as for Forsgården GK is assumed.

AppendixVII

Division of work.

This thesis has been carried out by Sandra Hansson and IdaMaria Persson. The division of the work has been equally distributed and has been done in close collaboration.

The code to the web application has been written by Sandra Hansson, but the design and layout has been developed by both Sandra Hansson and IdaMaria Persson.