PRODUCT CARBON FOOTPRINT OF HYDRAULIC AND PNEUMATIC COMPONENTS – CHALLENGES IN ACCOUNTING AND COMPARABILITY

Johannes Sprink[1]*, Katharina Schmitz[1]

[1] *RWTH Aachen University – Institute for Fluid Power Drives and Systems (ifas), Campus-Boulevard 30, 52074 Aachen*

* Corresponding author: Tel.: +49 241 80 47709; E-mail address: Johannes.Sprink@ifas.rwth-aachen.de

ABSTRACT

To achieve global climate protection goals, a reduction of greenhouse gas emissions is necessary. Accordingly, emissions from technical products such as fluid power components must be known over the entire Product Life Cycle. The Product Carbon Footprint (PCF) is used to systematically record the greenhouse gas emissions of a product.

For the calculation of a PCF, for each step in the life cycle, the inputs of material and energy have to be identified and analyzed. Within the context of a cradle-to-gate analysis, the focus is on the production phase and upstream processes. In a previous study carried out by the authors, a variety of fluid powered components were evaluated in regards of their greenhouse gas emissions during the production. Challenges that can arise in such accountings are presented in this paper. For example, in many cases the use of database factors is unavoidable due to the lack of primary data. However, determining of exact factors poses a problem that cannot be neglected. It is shown that even with similar preconditions extreme deviations in the results can occur. Examples for such results will be presented and explained.

Conclusions are drawn that may also be helpful when accounting products. Furthermore, recommendations are presented on how to deal with the calculation results of third parties.

Keywords: Product Carbon Footprint, Sustainability, Greenhouse Gas Emissions, Cradle-to-Gate

1. INTRODUCTION

The effects of climate change are now ubiquitous. It is reflected in the increase in temperatures and extreme weather conditions. These will occur even more frequently in the future [1]. Climate change is thus becoming one of the most significant risk factors for humankind and is determined mainly by the concentration of greenhouse gases (GHG) in the atmosphere. To counteract this, it is necessary to emit fewer greenhouse gases. In the Paris Climate Agreement, 190 countries agreed to the goal of limiting global warming to 1.5°C compared to pre-industrial times [2]. Other international agreements lay down further obligations in this regard. At the European level, for example, there is the EU Green Deal, in which the European Union commits itself to be ultimately climate neutral by 2050 [3]. In addition, the individual member states have, in some cases, made even more far-reaching commitments. The Federal Republic of Germany, for example, sets even stricter targets for annual emissions with its Climate Protection Act 2021 [4].

Industrial processes have a significant share in the emission of greenhouse gases [5]. The various regulatory measures mentioned are therefore aimed in particular at the manufacturing sector. In order to achieve savings, a systematic and uniform measurement of emissions is first necessary.

Various methods are available for accounting these emissions, which are standardized in different norms. These are generally based on the life cycle analysis (LCA) approach. A number of ISO standards should be mentioned, with ISO 14067 providing details on the balancing of greenhouse gases. The GHG Protocol standards are also widely used in the economy.

The fluid power industry, as a supplier of products for use in energy-intensive machinery, is of particular importance, as also shown in [6] and [7]. For exemplary products from the fluid power industry, cradle-to-gate studies regarding the GHG emissions were conducted. The usage phase of the products and the end-of-life treatment were not inspected for different reasons. For example the utilization cycles of fluid powered components vary greatly from one application to the next and are not known to the manufacturer.

In this paper it will first be described what kind of difficulties can arise during the accounting, because uniform accounting is not easy to achieve. This concerns, for example, the choice of uniform system boundaries, the level of detail of data collection and the choice of applicable factors from databases. Furthermore, the results of different accountings will be compared and discussed. Finally suggestions on the application of the findings of this study will be made.

2. ACCOUNTING OF GHG-EMISSIONS

GHG emissions during the life cycle of a product can be divided into three different scopes. Scope 1 includes a company's direct emissions. For example, these can result from the use of company vehicles or the use of fossil fuels in manufacturing processes or building operations. Scope 2 includes indirect emissions from the provision of purchased energy. All other emissions that occur indirectly during the life cycle of a product are included in scope 3. Depending on the stage of the life cycle, Scope 3 emissions are referred to as upstream or downstream. The Upstream includes all processes by third parties before the reporting company becomes involved. Downstream emissions are only considered in a cradle-to-cradle analysis and include, for example, energy consumption during the use of sold products and end-of-life treatment of products. An illustration of these scopes has been created by the GHG Protocol as shown in **Figure 1**.

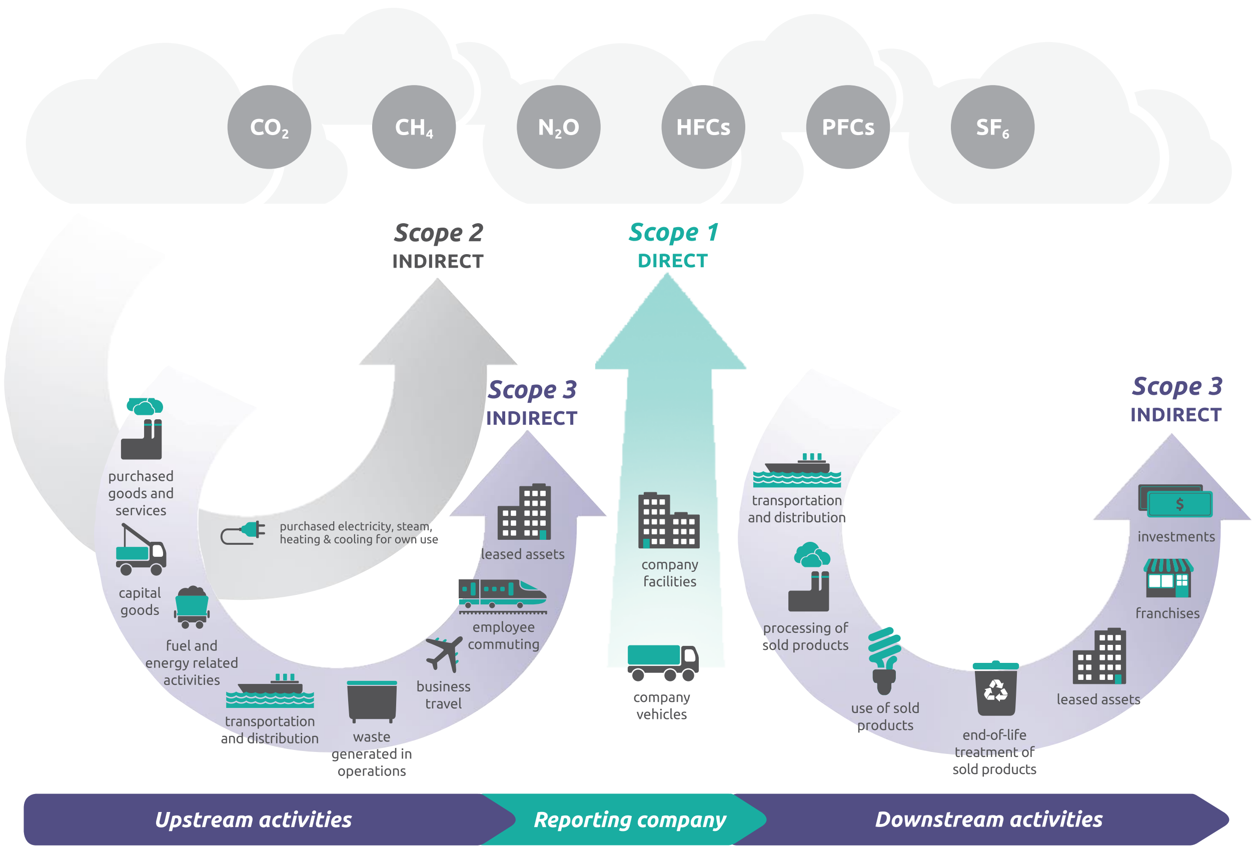

Figure 1: Overview of GHG Protocol scopes and emissions across the value chain [8]

In the context of carbon emissions accounting, a major challenge lies in the collection of data. This task involves a series of crucial steps. First, a detailed flowchart should be created to illustrate the entire operational process. Subsequently, it is imperative to identify and document all process steps that could potentially contribute to emissions. This not only involves direct emissions, but also the indirect emissions. Therefore, any inputs to the process must be considered. This may be the use of energy but also the application of components and raw materials.

Concurrently, a comprehensive inventory of the materials and energy inputs utilized within the process is essential to gain a comprehensive view of emissions sources. The practical implementation often involves the retrieval of data from Enterprise Resource Planning (ERP) systems. But overall, the process of data collection demands considerable effort of the involved parties. Not only does it involve a small number of people in a specific department, but it also requires a lot of communication with each unit involved in the production subsequent treatment of a product.

GHG accounting over the lifecycle of components has already been studied for many fluid-powered components, as shown in [9] and [10]. At ifas a further study has been conducted to compare the accountings of a variety of fluid powered components in regards of their greenhouse gas emissions during the production. This includes different hydraulic and pneumatic valves and actors as well as hydraulic pumps. Each of these were produced by different manufacturers. The goal was to achieve a uniform accounting process of all involved companies. The challenges of a consistent approach are described in the following. It is shown that the results are often poorly comparable despite the fact that they are conform to the GHG Protocol.

3. CHALLENGES IN ACCOUNTING

To get a comparable result, it is crucial to have uniform procedures for the data collection. In practical terms, however, various difficulties arise in the application of the norms and standards described. On the one hand, these standards leave a lot of leeway in their application. For example, the system boundaries and thus the scope of data collection in a large area can be chosen individually by each company. On the other hand, this is necessary to ensure general validity so that applicability in different subject areas is possible. The intention is that, if necessary, even services can be compared with the production of equivalent products. However, without further guidelines that are specific to particular product categories, this simultaneously makes the comparability of results more difficult. It also follows that a numerical value as the result of an accounting alone is not sufficient to assess the result of an accounting process. In addition, it is necessary to prepare a report that contains additional information. The preparation of such a report is required by all standards. However, only the contents of the report are specified, not a uniform format.

Within the context of the research carried out, it showed that the largest share of greenhouse gas emissions within the cradle-to-gate analysis of the inspected components is accounted for by Scope 3 emissions. This includes all emissions by upstream suppliers. Especially the production of raw materials is responsible for a large share of the total emissions. Depending on the scope of the individual analysis, transport-related emissions typically fall within the range of 1 % to 10 %. Nevertheless, it should be noted that emissions in other categories are also of significant importance. This is primarily due to the fact that changes are occurring in all areas of the life cycle. For example, in the case of "Fossil-free steel" production, the replacement of coal and coke with hydrogen was observed, signifying a critical shift towards sustainability [11]. These findings underscore the multifaceted nature of emissions accounting, where changes and innovations across diverse domains collectively contribute to the overall trajectory of carbon emissions.

Databases

At present, no exact numerical values are available for many processes in the life cycle. The reasons for this are manifold; especially in the case of multi-layered supply chains, it is still difficult to obtain reliable information on greenhouse gas emissions from each party involved. Therefore, in practice, so-called emission factors have to be taken from databases, although the data obtained from these can at best be a rough estimate of real processes. The data sets stored there originate from different sources and are regularly adapted to changed boundary conditions. For example, a change in the electricity mix in the country of manufacture of a material affects the balance. Therefore, in today's global supply chains, large fluctuations can occur over time despite unchanged products. The greater the proportion of database values used, the greater the impact on the final result.

A temporal influence also arises separately from the use of database factors. In the case of regular deliveries of raw materials, it happens that suppliers obtain the same material from different sources. Since greenhouse gas emissions are strongly dependent on the country of origin, this also leads to a temporal change in the environmental impact.

In the course of the research, many numerical values were calculated using emission factors taken from databases. For example, no participant had reliable data on the raw material used. Freely accessible data sources have cost advantages, but in some cases only provide older or inaccurate data sets, in extreme cases even obviously wrong data sets. For specific material, researching specific studies has also proven helpful. However, this is time-consuming and the data obtained in this way often still have to be transferred into a comparable context.

As has been described, databases provide poor accuracy. Provided that the databases used are of sufficient extend, more accurate information about one's materials is helpful. For example, many databases break down the emission factor of raw materials by percentage of primary material and country of origin, allowing a better approximation to be made. However, primary data is preferable at all times in order to realistically represent the actual processes and thus obtain an accurate calculation result.

An example on database values is presented in **Table 1**, where values for milling of metal are displayed. These values are represented per kilogram of material to be removed. It is important to note that specific definitions distinguishing between large and small parts were not provided within the dataset. Furthermore, it was observed that there is a substantial variation in these values, which is contingent upon the size of the respective parts. Also, there may exist uncertainty regarding the comprehensiveness of the information encompassed within the database values, including aspects such as the selection of specific transport routes and material treatment methods.

Table 1: Example: Milling of metals – Database ecoInvent 3.8 [1]

	Average	Large parts	Small parts
Cast iron	0,148 kWh	0,0659 kWh	0,706 kWh
Steel	0,474 kWh	0,211 kWh	2,26 kWh

4. COMPARIBILITY OF CALCULATION RESULTS

In order to objectively compare the greenhouse gas emissions of similar products across manufacturers, it is necessary to have identical prerequisites. The aim of the research, which was carried out in cooperation with various manufacturers of pneumatic and hydraulic components, was to archive such a uniform accounting across different manufacturers. Exemplary components such as hydraulic and pneumatic valves and actuators, as well as hydraulic pumps, were examined and an accounting according to the GHG Protocol was performed. For various reasons, which are explained below, it was not possible to achieve reliable comparability, and a comparison has not yet been possible within the context of the research carried out.

The overall results show that the numerical values of the results reflect a different level of detail between the calculation results of the individual participants. In particular, scopes 1 and 2 are mapped in much greater detail than scope 3 upstream for most companies. This is due to the fact that the data on the companies' own processes is available to a higher degree of accuracy for all companies than the data from the suppliers, insofar as they were able to provide data at all. Scope 3 downstream was not investigated during the study, but might be even harder to account, because no standardized utilisation-cycles apply for all the specific applications of different customers.

It was not possible to determine final results for the emissions during the manufacturing phase of some products. For example, specific numerical values were not available yet. Therefore, assumptions were used for these in many places. In some cases, for example, no data is available on material processing in the supply chain. In these cases, the GHG Protocol specifies that conservative estimates be used for the missing data. This prevents a realistic comparison of the products in the individual categories.

For some products, certain necessary data is not known in detail. This concerns, for example, the power consumption of individual processing machines, for which assumptions and estimates have been made. In the absence of measuring instruments for individual processing machines, only the general consumption of a larger unit can be taken and allocated to all the products produced in that unit. As a result, only a less precise result can be achieved. Similarly, for many other products, some small components whose weight is in the range of a few grams are not taken into account. Provided that an appropriate estimate of the impact on the final result predicts only an insignificant impact on the overall result, this disregard is consistent with the requirements of the GHG Protocol.

Examples on specific comparisons

Two internal gear pumps from different manufacturers were analysed as part of the research. A comparison of the two pumps is shown in **Figure 2**. Normalization to 100% of the value of pump A was performed. Pump B weighs approximately 4 times more than pump A. Nevertheless, the calculation result of pump B in comparison with pump A indicates a significantly lower greenhouse gas emission. However, this is most likely due to the different level of detail in the analysis. Irrespective of the assumptions made in database values, for example, processing efforts at the suppliers were explicitly recorded for pump A. The value of the raw material in relation to the product weight also differs by a factor of about 4 for both pumps. However, this is probably also due to the greater depth of observation. For example, experience shows that emission factors taken from databases for a general structural steel are significantly lower than factors for a precisely specified alloy of the material actually used.

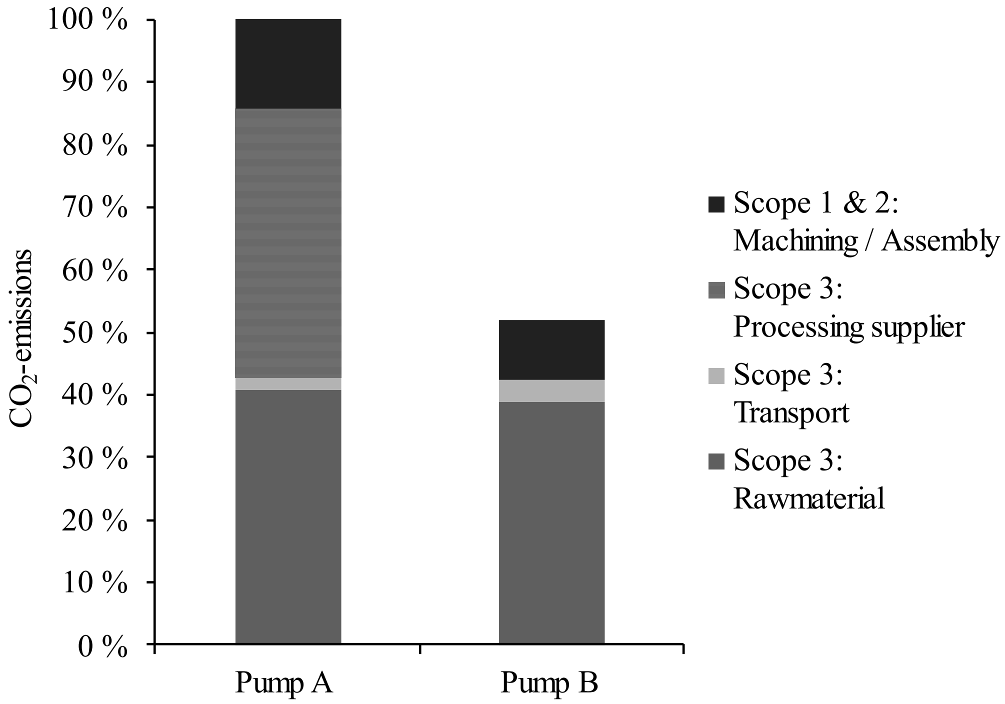

Figure 2: Comparison of internal gear pumps

A similar result is also found for pneumatic valves. **Figure 3** illustrates a comparison of the balancing results for two 5/2-way valves. It can be seen that there is also a large discrepancy between different manufacturers in this case Valve B is approximately 50% heavier as Valve A, but seems to emit 500% of the carbon emissions. The reasons for this again might be a more detailed analysis. In the case of valve B, for example, scrap treatment and surcharges for uncertainties are taken into account. The apportionment of general energy consumption of (electricity, heating, cooling) is also comprehensively taken into account, and even the heating of corridors and other production-related areas, for example, is included in the result of valve B. Corresponding values may optionally be added in accordance with the GHG Protocol, which represents a realistic balancing, but also leads to a higher result. In addition, the different prerequisites prevent a uniform comparison between different manufacturers.

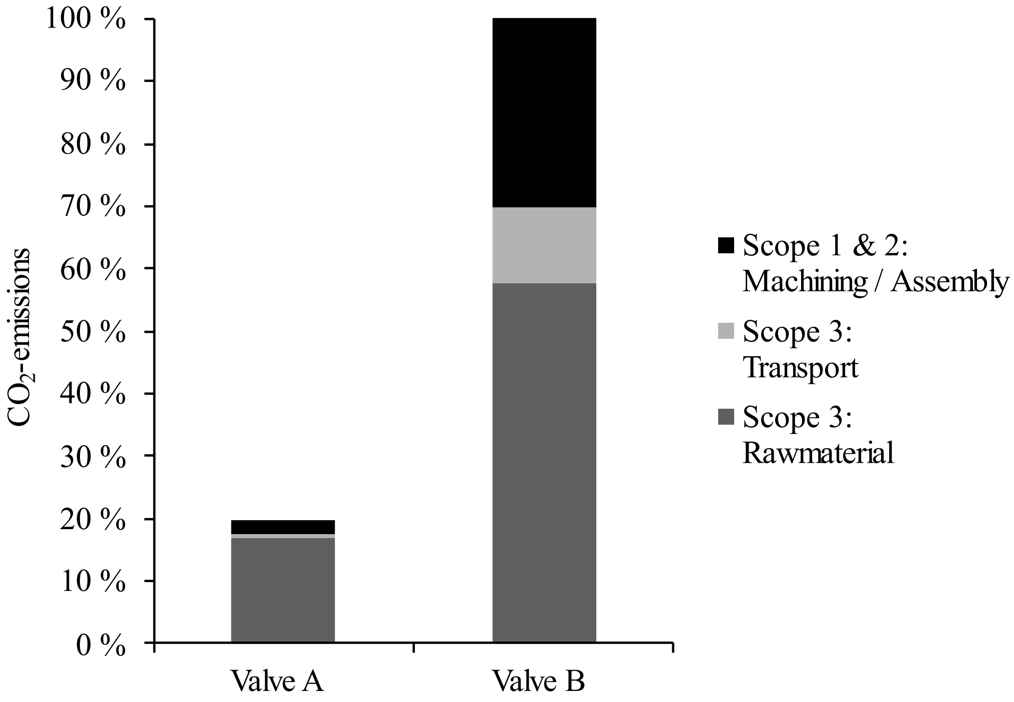

Figure 3: Comparison of pneumatic valves

5. CONCLUSION AND RECOMMENDATIONS

Based on the results shown, it can be seen that even with a fully standard-compliant procedure, a less intensive analysis can result in a lower numerical value for greenhouse gas emissions in the calculation. In this context, there is a risk that companies preparing their balance sheets will deliberately consider certain process steps less precisely in order to convey a positive impression of their own greenhouse gas balance. The intended estimation of unknown correlations can also easily be chosen in such a way that the results are presented more positively than they are. Particularly in competition with other companies, there is therefore a risk that the published figures do not reflect the real environmental impact.

An important step in communicating with suppliers is therefore to always request the corresponding report in addition to the balancing result. This is because the system boundaries selected and assumptions made must be documented in it, so that an insight into the calculation methodology is gained.

A further step towards uniform balancing can be taken by more specific regulations and standards. For example, a VDMA standard sheet has been drawn up in which more detailed approaches are prescribed for many points, which can also be applied in a practical manner in mechanical and plant engineering in particular. In addition, various characteristics are defined on the basis of which different quality criteria can be derived. By specifying them, further transparency can be created and a faster assessment of the result can be made. The creation and application of specific Product Category Rules (PCRs) in accordance with DIN EN ISO 14025 can also help to achieve standardization.

However, trust in business partners will remain an important criterion for assessing published emission values in the foreseeable future. Certification of a company's accounting methodology by neutral parties can have a positive influence here. However, neither more detailed standardization nor certification can completely prevent differences in the results of different accounting methods.

The necessary reduction in greenhouse gas emissions can therefore only be achieved by working together to make all industrial processes as climate-neutral as possible.

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NOMENCLATURE

ERP Enterprise Resource Planning
GHG Greenhouse Gas
LCA Life Cycle Analysis
PCF Product Carbon Footprint
PCR Product Category Rule

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