PCF PILOTPROJEKT DEUTSCHLAND

CASE STUDY TCHIBO PRIVAT KAFFEE RARITY MACHARE BY TCHIBO GMBH

Documentation.

Case Study undertaken within the PCF Pilot Project Germany

Content

1 Preface

The case study "Tchibo Privat Kaffee Rarity Machare" that follows was elaborated within the scope of the Product Carbon Footprint (PCF) Pilot Project Germany by Tchibo GmbH in association with Öko-Institut e.V. (Institute for Applied Ecology). For the PCF Pilot Project, Tchibo GmbH joined nine other companies to pursue, together with the project initiators – WWF Germany, Öko-Institut (Institute for Applied Ecology), the Potsdam Institute for Climate Impact Research (PIK) and THEMA1 – the following project objectives:

1. *Gaining experience*: On the basis of concrete case studies, the project initiators and the participating companies gain experience with the practical application of current methods for determining carbon footprints and examine the efficiency of these methods (ISO[1] standards for life cycle assessment, BSI[2] PAS 2050).
2. *Deriving recommendations:* Based on the findings of the case studies, recommendations are derived for the further development and harmonisation of a transparent, scientifically founded methodology for determining the carbon footprint of products. The pilot project explicitly refrains from developing its own methodology.
3. *Communicating results:* Consumers must be informed of the product carbon footprint in a scientifically sound and comprehensible manner. To this end, the project stakeholders are holding discussions on reliable communication on a sectoral, company and product level to foster climate-conscious purchase decisions and use patterns. The relevance in terms of increasing the climate consciousness of consumer decision making is crucial to these considerations. The pilot project explicitly refrains from developing its own climate-related label since the current methodological conventions are not sufficiently consistent and are still under discussion, meaning that its significance in terms of possible courses of action would therefore be low.
4. *Standardising internationally*: The findings reached and the recommendations derived contribute to a situation in which the PCF Pilot Project Germany actively helps to shape the international debate on the determination and communication of carbon footprints.

[1] International Organization for Standardization.
[2] The British Standards Institution.

The definitions and uses of the term "product carbon footprint" differ internationally. Within the scope of the PCF Pilot Project Germany, the project stakeholders agreed on the following definition:

"Product carbon footprint describes the sum of greenhouse gas emissions accumulated during the full life cycle of a product (good or service) in a specified application."

In this context, greenhouse gas emissions are understood as all gaseous materials for which a Global Warming Potential coefficient was defined by the Intergovernmental Panel on Climate Change (IPCC). The life cycle of a product encompasses the whole value chain – from the acquisition and transportation of raw materials and primary products over production and distribution to the use, recycling and disposal of the product. The term "product" is used as a generic term for goods and services.

The project initiators and participating companies regard the international standard for life cycle assessment (ISO 14040 and 14044) as the basic methodological framework for determining a product carbon footprint. Moreover, this standard is the most important foundation of the British PAS 2050 as well as of the above-mentioned dialogue processes of the ISO and the World Business Council for Sustainable Development/World Resources Institute[3]. Therefore, within the scope of the pilot project, ISO 14040/44 constituted an essential basis for the work carried out on methodologies and thereby for the case studies themselves.

Many of the basic methodological conditions of ISO 14040/44 can be applied in the case of the PCF methodology, but several have to be adapted. Some terms of reference of the ISO 14040/44 are loosely formulated, making it necessary to examine whether it is possible to develop less ambiguous terms of reference which have a comprehensive or product group-specific foundation. This would simplify the comparability of different PCF studies. In addition, within the course of the case studies, the significance of PCF compared to other environmental impacts in the product life cycle was analysed in varying detail. From the perspective of the PCF Pilot Project, this analysis is crucial to the securing of decisions and approaches to communication, which are made and developed on the basis of PCF. Furthermore, creating clearer terms of reference constitutes one of the greater methodological challenges in this context, also in respect of international harmonisation and all applications where public communication of the PCF is intended.

Each participating company selected at least one product from its portfolio for which a PCF was determined. In this way, methodological frameworks or rules of interpretation regarding the ISO 14040/44 could be practically tested using a specific case study. In turn, specific methodological issues also emerged from the case studies. The broad spectrum of products selected for the case studies made for a comprehensive discussion. The

[3] With regard to the WBCSD/WRI process, a final decision has not yet been taken. However, it can be assumed, given the current status of the discussion, that a decision on the ISO 14040/44 will be taken in the coming weeks.

involvement of companies from very different sectors in the PCF Pilot Project was challenging but also fruitful, constituting an essential prerequisite for the development or optimisation of a methodology which could be used as broadly as possible. The case study “Tchibo Privat Kaffee Rarity Machare” by Tchibo GmbH constituted an important component of the project, on the basis of which – together with the diverse experiences gathered in terms of carbon footprinting – the findings and recommendations were developed according to the project objectives.

The most important results of the pilot project are summarised in a paper entitled “*Product Carbon Footprinting – Ein geeigneter Weg zu klimaverträglichen Produkten und deren Konsum? – Erfahrungen, Erkenntnisse und Empfehlungen aus dem Product Carbon Footprint Pilotprojekt Deutschland* “. This paper, along with much more information on product carbon footprinting and the PCF Pilot Project, can be found at:

www.pcf-projekt.de

The work carried out within the pilot project should not be understood as the final word on the determination and communication of product carbon footprints. Therefore, the project partners are happy to receive intensive feedback from interested stakeholders, also with regard to the case study presented in the following. Based on this feedback and the project findings, the project initiators and partners wish to actively support international debates on the harmonisation of product carbon footprinting by virtue of their findings. Only in this way, with the help of an internationally accepted standard, can PCFs be determined, assessed and reliably communicated in a uniform and comparable fashion.

Berlin, 26 January 2009

2 Executive Summary

- Als einen weiteren wichtigen Baustein seiner Aktivitäten im Klimaschutz sieht Tchibo die Analyse der Treibhausgasemissionen in der Wertschöpfungskette Kaffee. Dazu wurde beispielhaft eine auf einer Rainforest Alliance zertifizierten Farm angebaute Kaffeerarität (Rainforest Alliance Certified™ coffee), die Tchibo Privat Kaffee Rarität Machare, ausgewählt. Der Anbau nach den Regeln der Rainforest Alliance ist besonders stark auf Umweltschutzaspekte ausgelegt.
- Durch eine in diesem Fall sehr gute Erfassungsqualität in allen Stationen des Produktlebenszyklus wurden fast ausschließlich Primärdaten verwendet.
- Ein Hot Spot der Treibhausgasemissionen ist im Anbau, hier insbesondere bei Produktion und Einsatz der verwendeten Agrarchemikalien (z.B. Pflanzenschutzmittel und Dünger) zu finden. Ein weiterer Hot Spot ist die Zubereitung des Kaffees durch den Endverbraucher.

- Aufgrund geringerer Flächenerträge bei völligem Verzicht auf Agrarchemikalien sind weitere Untersuchungen zu möglichen klimaoptimalen Anbauweisen erforderlich.
- Zur endgültigen Bewertung und Einordnung der gefundenen Ergebnisse ist die Erfassung der PCFs von anderer Anbaumethoden notwendig.
- Die Zubereitungsmethode durch den Endverbraucher ist ebenfalls relevant. Insbesondere die Nutzung von Kaffeevollautomaten erzeugt hohe Emissionen. Inwieweit eine Lenkung des Konsumentenverhaltens möglich und sinnvoll ist, ist zu prüfen.

- For Tchibo, the analysis of greenhouse gas emissions in the supply chain of coffee is one important aspect of its activities towards climate protection. For that reason, an exemplary Rainforest Alliance Certified™ coffee, Tchibo Privat Kaffee Rarität Machare, was chosen. The cultivation according to the standards of the Rainforest Alliance is particularly focused on aspects of climate protection.
- Due to high quality data capture in every step of the product life cycle, primary data could almost solely be applied.
- One hot spot of greenhouse gas emissions is the coffee cultivation, in particular the production and the use of agrochemicals (e.g. fertilizer & plant protecting products). Another hot spot is the preparation of the coffee by the consumer.
- Further examinations about more climate-friendly possibilities of cultivation methods are required as the total abandonment of chemicals leads to poorer crop yields.
- To survey a final validation and a classification of the identified results, the acquisition of PCFs of other cultivation methods is necessary.
- The method of coffee preparation by the consumer also is relevant. Especially the usage of bean-to-cup coffee machines produces high emissions. It should, however, be checked, how far an influence of consumer behaviour would be possible and even reasonable.

3 Company’s Profile

Based in Hamburg, Tchibo is one of Germany’s largest internationally active retail and consumer goods companies – and the world’s fourth-largest coffee producer. Founded in 1949, Tchibo stands for a unique business model: it combines first-rate roasted coffee expertise and an innovative spectrum of consumer merchandise that changes on a weekly basis. To distribute its products, Tchibo relies on a unique multi-channel sales system including its own shops, a successful mail order and Internet business as well as an extensive retail presence.

Climate protection is one of the biggest challenges of our generation. We at Tchibo are aware of our responsibility for the climate, too. That’s why we have set ambitious targets and we put into effect precise measures towards climate protection.

A lot of our products have a complex supply chain and they often have to cover long distances. Due to that we try to create all processes of the product life cycle as resource-friendly as possible to protect the climate.

These are some examples of our activities in this section:

- In the area of raw materials, we are working with internationally accepted multi-stakeholder standards, i.e. those of the Rainforest Alliance as well as the FSC, which are particularly focused on the compatibility of the environment and climate of coffee cultivation respectively forestry.
- Since January 2008, we have been purchasing the electricity for our German administrative buildings, roasteries and warehouses from an ‘ecotricity’ supplier whose electricity comes from sustainable sources. Our German shops purchase this electricity since January 2009.
- Tchibo is an active partner in the ‘Logistics towards sustainability (LOTOS)’ project. In collaboration with the Hamburg - Harburg University of Technology and the German Federal Ministry for the Environment, we’re currently implementing measures that lead to a further ambitious reduction of greenhouse gas emissions in our transport processes.

The participation in the “Product Carbon Footprint” pilot project is another component in our climate protection activities by what we’d like to transfer further meaningful measures for the product-related climate protection.

4 Organisation and Procedures

The case study was coordinated by the Corporate Responsibility department.

Experts of other departments relevant for the value chain of the examined coffee like Purchasing Food, Logistics and Manufacturing surveyed the essential data and like the Corporate Communications department, they were partly involved in the superior task forces.

Öko-Institut e.V., Rainforest Alliance, the owner of the Rainforest Alliance Certified™ coffee farm, the operator of the coffee mill in the origin as well as the supplier of packaging and other materials supported the data capture.

5 Goals and Scope

The PCF pilot project aims to develop a sound methodology for calculating product-related greenhouse gas emissions that may be used further in business to business or business to end-user communications. Until today, no standard format for calculating product-related greenhouse gas emissions or product carbon footprints (PCFs) has been developed. However, there are several areas that will deliver important insights for a methodological approach.

First is the international norm on life cycle assessment, ISO 14040 Series. ISO 14040/14044 started to materialize in 1997 and presents an international standard that links life cycle assessments with due diligent processes, data quality control and environmental management.

Secondly are standards and approaches for calculating corporate greenhouse gas balances. They too may provide important information and insights on how to calculate certain aspects of the product value chain. Here are an ISO standard (ISO 14064) as well as a voluntary industry initiative, the Greenhouse Gas Protocol, that are worth noting.

Thirdly has the British Standards office published its final version of the PAS 2050, “Specification for the assessment of the life cycle greenhouse gas emissions of goods and services”. PAS stands for Public Available Specification and is a non binding standard, hierarchically below ISO norms. However, both PAS and voluntary initiatives have the power to become de-facto norms and influence the international norm-setting process by virtue of establishing a methodology.

Thus the major goal of this study is to gain experience with an applied PCF and to inform the process for developing a sound PCF methodology. While life cycle assessments have been used traditionally in a scientific way and for internal purposes, it is apparent by the discussions that a PCF will be meant more as a means of communicating performance to business and private customers. Therefore the question of communication and of goals and aspirations is intrinsically linked with developing a sound methodology.

The following PCF was carried out in accordance with the ISO 14040/14044 norm. It was decided that the ISO 14040/14044 approach presents the most comprehensive approach to date. It can be expected that other environmental effects, which may be important to consider, can be detected by using the full life cycle assessment approach. However, there might be social effects and socially affected along the value chain, which will not be covered with a traditional ISO 14040/14044 life cycle assessment. Social aspects always belong in a comprehensive assessment of responsible behaviour, good corporate conduct and the presentation of sustainability.

This pilot study tries to find answers to the following questions: What does a PCF say? What conclusions can be drawn? Where are the limits? Where are the risks? How can it be used? In which way does it inform the consumer and user? And last but not least is it suitable indicator for responsible performance?

In accordance with ISO 14040/14044, the following assessment is based on a functional unit (FE). Functional units serve to normalize elementary flows and environmental impacts. The Öko-Institut e.V. and Tchibo have decided to use one cup of Tchibo Privat Kaffee Rarity Machare as the functional unit (FE).

5.1 Objectives of the Case Study

As mentioned in Chapter 3, climate protection is an essential topic for us.

By balancing the PCF of coffee we wish to obtain the following benefits:

- Information about climate efficiency of a selected supply chain
- Identification of hot spots of GHG emissions
- Identify possible reduction potentials
- Practical know-how about PCF
- Supporting the international harmonisation of methodology
- Prospects of a communication which fulfils all requirements

5.2 Product Selection and Definition of the Functional Unit

Rarity coffee is characterized as coffee from a single source and single species compared to other coffee which is normally blended from various sources and species. In this study, the targeted coffee is Arabica and originates from northern Tanzania. Data on the cultivation is collected from two farm parts, Machare and Uru Estate on the slopes of Mount Kilimanjaro near Moshi town. Machare has 25 plots while Uru has 22. They are adjacent plantations under the same management and belong to the same farmer. The coffee from these two plantations has the same quality. Tchibo normally markets four types of rarity coffee each year which are limited in amount and not available all year and not in the same season. The Tchibo Privat Kaffee Rarity Machare is being cultured at these two plantations. Ripe coffee is harvested as coffee fruit, the so-called coffee cherry, and initially is processed in the farm plant and local mill. Then, the intermediate product is shipped from Tanzania to Germany, and experiences successively re-processing, distributing, consuming, till the end stage of life cycle of coffee.

Coffee as one of the most popular daily beverages fulfils different functions, e.g. enjoyment or refreshment.

A functional unit serves to normalize all flows within the scope of the study. In addition, it can also be a basis for the comparison of different products. The functional unit of this study is defined as **one cup of brewed Tchibo Privat Kaffee Rarity Machare** which is **equivalent to 7 grams of coffee powder with 0.125 litre of water** consumed.

5.3 System Boundaries

The value chain of the coffee production is roughly divided into seven stages which include cultivation as well as primary processing in Tanzania, overseas transportation of the intermediate product, reprocessing in Germany, distribution from wholesalers to retailers, consumption and disposal. The strict principle of life cycle analysis implies that all material and energy inputs within this system have to be inventoried and traced back to natural resources. An overview of the definition of the system boundaries of this coffee Carbon Footprint (CF) study is illustrated in Figure 1.

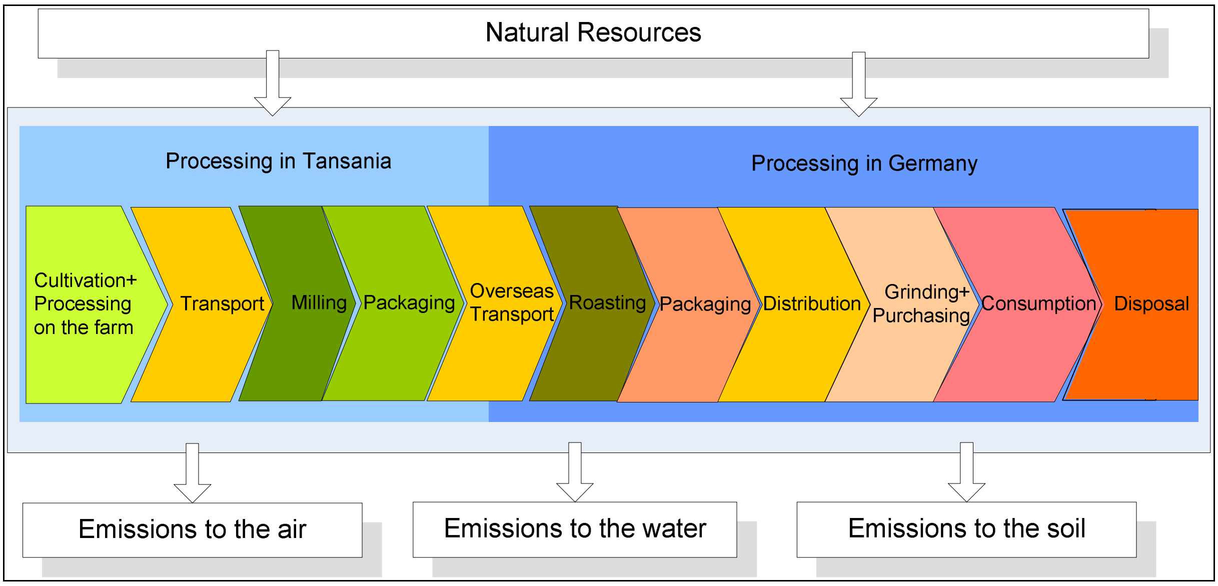


Figure 1: Overview of the system boundaries of this coffee Carbon Footprint study

Each of the unit processes indicated above will be discussed in more detail in the following chapters on modelling.

The following processes are excluded from the analysed system:

- *Human energy inputs*, for example coffee cherries picked by workers is excluded according to PAS 2050.
- *The potential environmental impacts associated with the production of capital equipment and facilities*. Since the impacts are expected to be very marginal due to the long lifespan of capital equipment and facilities they are not expected to have a significant influence on the result. This proceeding is also recommended by PAS 2050.
- *Carbon storage by shade trees whilst culturing the coffee shrubs*. In principle the carbon storage by shade trees should be considered as it is directly connected to the coffee plantation but as no data were available this aspect has to be analysed further in future studies.
- *Input of Micro-organisms*. For example the manufacturing process of the biological pesticide Thuricide whose active ingredient is 0.8 % Bacillus Thuringiensis (Bt). Bt is

a soil borne organism and the remaining 98.2 % of the substance are declared as an inert substance. In addition, the used amount of this pesticide comprises less than 1 % of all agrochemicals. Therefore the impact is expected to be very limited and its neglect is expected to have no influence on the result.

- *The production process of sisal bags used by farmers* in the Tanzania inland transportation of the coffee from the farm to the mill plant. As sisal bags are transported back to the farm and reused each year, their impact is expected to be neglectable.
- *Production of manure*. No data were available for the production of manure originated from the cattle on the farm grounds. This data gap will not have significant impact on the result.

Deviation from PAS 2050: Another point worth noting is that in PAS 2050 the transport of consumers to and from the point of sale (shopping tour) is excluded from the assessment of the CF. However, it was agreed in the CF pilot project that the shopping tour will be considered in order to demonstrate whether and how much the accordant global warming potential affects the overall results.

5.4 Data Sources and Data Quality

The data sources adopted in the inventory can be differentiated into primary and secondary data[4]. Primary data represent the specific processes and activities related directly to the investigated product. However, for some upstream and downstream processes, like the production of ancillary materials, primary data are difficult to obtain. In this case the secondary data are used for the inventory. This proceeding is in consensus with PAS 2050.

According to PAS 2050 as well as ISO 14040 and 14044 the data should fulfil certain quality requirements concerning time-related coverage, geographical coverage and technological coverage:

- <u>Time-related coverage</u>

The specific primary data throughout the life cycle of the coffee production were obtained mostly from Tchibo GmbH and reflect a robust inventory basis. The reference year is the 2007/2008 coffee production period:

The rarity coffee under investigation will be sold to consumers in 2009 and is produced from November 2007 till about December 2008. The used primary data are not referring to the

4 The sources can also be named as specific and general data respectively.

actual production period but the previous one as the production period of the rarity coffee was still going on during before this study was finished. This proceeding is justified as it delivers a very good proxy: According to farm management e.g, there is not much change in farming practice. Also the differences in the roasting process are expected to be marginal.

Due to the available general datasets in the used databases, the temporal references range between 1999 to 2008, with some modules for chemicals originating only from 1987 (no other adequate data were available). In generally, a near-term time frame has been selected for this study, whenever available.

- Geographical coverage

The main processes during the life cycle of the analysed rarity coffee take place in two different countries (Tanzania and Germany). Additionally upstream and downstream processes covered by general data may take place in further countries (e.g. exploitation of resources). Both were considered concerning the choice of data:

The primary data on coffee cultivation and processing in the mill stem from Tanzania. The data on processing, distribution and consumption are related to Germany. The secondary data used in the analyses also - as far as possible - focus on the specific regions.

The concrete geographical coverage is explained together with the time-related coverage and the dataset sources in the accordant chapters.

- Technological coverage

In general the data for the specific core processes, i.e. logistics, roasting, packaging, refer all to the state-of-the art technology either in the respective country or in Europe.

The data on cultivation on the other hand represent a very high standard concerning the use of pesticides and the cultivation method in general (e.g. shaded polyculture system). The Machare Estate is not representative for coffee plantations in general or within Africa in specific and is certified according to the standards of Rainforest Alliance.

- Precision, completeness and representativeness, uncertainty of data and data sources

In generally, the data sets used for the inventory provide a robust and reliable data base. Either specific primary data or representative secondary data were used whenever available. As for some missing data because of scarce sources or unknown natural processes, these are clearly stated in the corresponding chapter.

- Consistency and reproducibility of data used

In the corresponding models the used data and data sources are described as detailed as possible. The life cycle inventory is seen to be consistent and reproducible.

A detailed list of the used data modules is shown in the chapter "Documentation of the Data".

5.5 Allocation

Primary data

Roasting process: certain wastes from the roasting process are sold as equivalent to wood pellets and could therefore be seen as co-product. But as the clear main product of the process is the roasted coffee, the impacts of the process are fully connected to the product coffee, no allocation is done. The potential positive effect due to the replacement of other energy sources (wood pellets) is only considered within a sensitivity analyses.

Secondary data

The allocation procedures within secondary data sets (e.g. electric grid, production of chemicals) are described there.

5.6 Treatment of particular emission sources

- **Renewable resources (refer to PAS 2050):** The national average energy emission factors for the renewable energy are used for Tanzania (electric grid is dominated by hydro power).
- **Direct and Indirect Land Use Change:** not relevant as the considered coffee plantation originates from the 1930ies. Rationale according to PAS 2050: "*Where it can be demonstrated that the land use change occurred more than 20 years prior to the assessment being carried out in accordance with this PAS, no emissions from land use change should be included in the assessment as all emissions resulting from the land use change would be assumed to have occurred prior to the application of the PAS*."
- **Aircraft emissions:** not relevant as transportation is done by ship or lorry.
- **Fertilisers:** The application of fertilisers on the field leads to the generation of N_2O due to certain processes in the soil. This effect was considered in the calculation. The N_2O emission was estimated using Equation 11.1 and default emission factors introduced by IPCC guidelines (IPCC Guidelines for national greenhouse gas Inventories, volume 4, 2006).

6 Inventory and Calculation

This section describes each phase of the life cycle for rarity coffee. Data Inventory and related assumptions are clarified in the accordant chapter.

6.1 Processes in Tanzania

The processes in Tanzania include the cultivation of coffee, the primary processing in the farm plant, transportation of parchment coffee from the farm to the local mill, the stripping process in the mill, the transportation of green coffee[5] from the mill to the harbour as well as the transport within Tanzania and the energy consumption of the terminal handling at harbour.

6.1.1 Cultivation of coffee

The inventoried processes for the cultivation of coffee encompass the use of agrochemicals and fuels on the field and their associated emissions. Additionally the connected upstream processes like manufacturing and transport were considered. Also, the downstream chain involving the reuse of residues (e.g. pulp) as organic fertilizers is accounted for. The different processes are illustrated in the following figure.

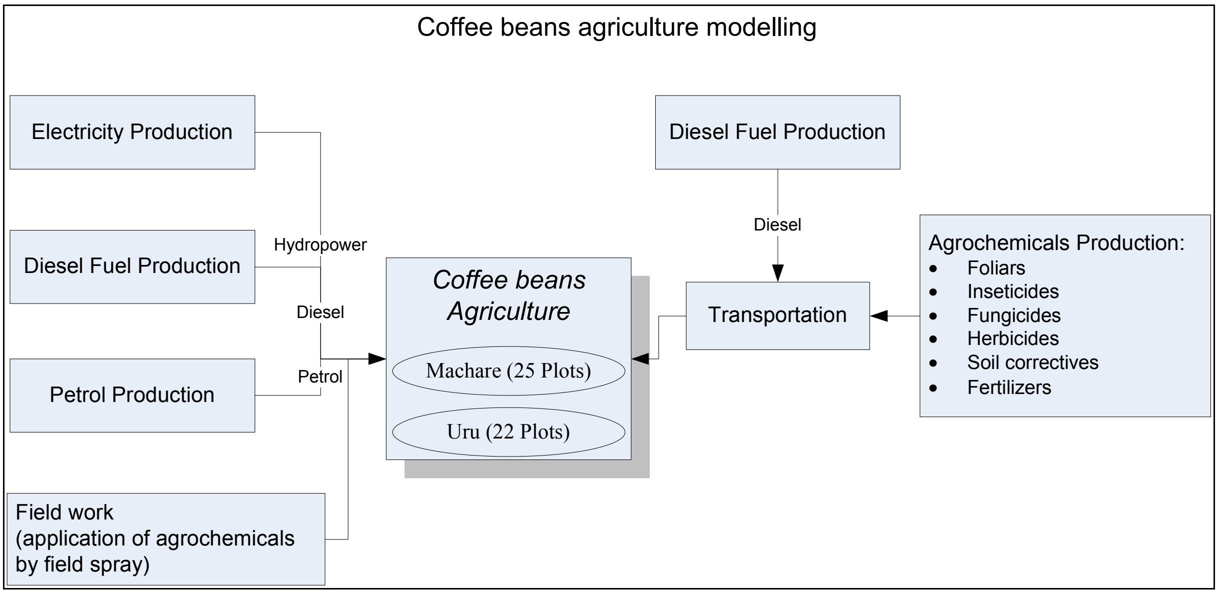


Figure 2: Processes under consideration connected to the cultivation of coffee.

The rarity coffee is cultivated as shaded polyculture system. Almost 6.000 shade trees with up to 100 years age already exist on the farm. Additionally many new shade trees have been planted on the farm during the last years. The CO_2-fixation of the shade trees connected to the coffee cultivation period under consideration should in general be taken into account. Due to lacking data concerning the kind of shade trees and the probable amount of CO_2 taken from the atmosphere during the cultivation period this aspect was neglected. Nevertheless future studies should have a closer look here.

[5] Green coffee means all coffee in the naked bean form before roasting [ICO 2007]

On the Machare farm coffee is not intercropped with any other economically valuable food or cash-crop which makes the cultivation different to traditional smallholder coffee farms in the Kilimanjaro region.

The uptake of atmospheric carbon by the coffee shrub was assumed zero as the economic life time of the coffee shrubs is expected to be 20 years. Reason is that the carbon dioxide re-emitted to the atmosphere within the 100-year from subsequent processes shall be excluded from the assessment complying with PAS 2050 Clause 5.4.2.3.

Moreover, according to PAS 2050 Clause 5.5, the assessment of the impact of land use change shall include all direct land use change occurring on or after 1 January 1990. The two plantations in this study started culturing coffee in the year 1930, although owners of plantations changed irregularly. Therefore, there are no GHG emissions arising from direct land use change based on this limited threshold year.

Modelling of electricity generation in Tanzania and energy related processes on the farm

In general, Tanzania is a country rich in water resources and the electric grid in the country is dominated by hydro power. The farm mainly uses electricity (low and medium voltage) from the national grid. Additionally the farm possesses micro hydropower electric units (500 Watt) that are delivering energy for the work camp with 20 people and the security lights at the processing factory. Further on diesel driven generators are used when the national electricity supply is down.

The subsequent table shows the accordant amount of consumed energy and the referred data sources:

The data for electricity from Tanzania hydro power stem from GEMIS 4.42. As for the diesel and petrol upstream processes, specific data for Tanzania were not available. Hence, the European datasets from EcoInvent was used, assuming that the processes and their impacts are similar.

The data in contain the overall amounts of consumed energy on the farm both due to field work and the farm plant (for processes in farm plant see chapter 6.1.2).

Table 1: Energy consumption per 1000 kg of coffee cherries

Parameters	Amount	Unit	Name of Dataset used	Temporal / geographical Reference	Data source
Energy Inputs					
-Electricity (Hydropower)	8.87*	kwh	Hydro-dam-Tan-Ruhudji	2000/TZ	GEMIS 4.42
-Diesel	225.87	kg	Diesel Production (lead-free)	2000/RER	EcoInvent 2.0
-Petrol	47.23	kg	Petrol Production unleaded	2000/RER	EcoInvent 2.0
Field work (machinery)	59	ha	application of plant protection products, by field sprayer	2002/CH	EcoInvent 2.0

* The indicated amount of consumed electric energy on the farm seems to be rather low and might be underestimated.

With respect to the operation activities on the field, most of them are done by hand, such as row weeding, pruning, de-suckering, applying most of fertilisers and pesticides as well as harvesting, and therefore are excluded from the scope. Additionally, all irrigation is driven by gravity without the need for electric energy for pumps etc.. For the application of agrochemicals diesel driven machinery (e.g. tractor sprayers) is necessary. The direct emission data, which is correlated to the field area of the application (59 hectare), are extracted from EcoInvent: It takes into account the direct emissions to the air from combustion and the emissions to the soil from tyre abrasion during the working activity. The machinery itself is not within the scope of this study as it belongs to the capital goods.

Modelling of agrochemicals

The modelling of the applied agrochemicals encompasses the production of the chemicals, their transportation and N_2O emission from the soil connected to the application of fertilisers (see below). The input of agrochemicals on the farm refer to foliar fertilizers, mineral fertilisers, organic fertilisers, insecticides, fungicides, herbicides and certain agrochemicals for adjustment of soil. Overall 28 kinds of agrochemicals are involved. Their production has been modelled according to either the corresponding nutrient contents (fertilisers) or the active ingredients (pesticides). An overview of the used data sources, the active ingredients and the referred substances are listed in chapter 13.1.1.

Concerning the transportation of the agrochemicals to the farm the following assumptions were made based on information from the farm management (see table below):

- Either agrochemicals are transported by pickup together with other purchases from shops in the area. The pickup modules include 8 trips with a distance of 16 km each and 1 trip with a distance of 80 km.
- Or agrochemicals are transported by lorry to the farm. The lorry modules include 10 trips with a distance of 16 km each.

The transportation model simulating pre-Euro situation from Tremove 2.7 was used to calculate energy requirements and emissions from pickup and lorry transportation in Tanzania.

Table 2: Transportation of agrochemicals

Name of modules	Vehicles needed	Distance (one-way)	Datasets	Time / Geography	Dataset source
Pickup 1	8	16 km	Solo-lorry, <7,5t 80erJahre	1980er / pre-Euro	Tremove 2.7
Pickup 2	1	80 km			
Lorry	10	16 km	Solo-lorry, 7,5-12t 80erJahre	1980er / pre-Euro	

Besides the production and transportation of agrochemicals, direct N_2O emissions from soils associated with N-containing fertilizers were taken into account. The reason is that an increase in human-induced N additions enhances nitrification and denitrification rates in soils which result in ammonia. The ammonia subsequently is converted to N_2O in the pathways of N. The N_2O emission was estimated using Equation 11.1 and default emission factor introduced by IPCC guidelines (IPCC Guidelines for national greenhouse gas Inventories, volume 4, 2006).

6.1.2 Modelling of the processes connected to the harvested coffee beans on the farm

The processes on the farm connected to the harvested coffee beans are illustrated in Figure 3: Ripe coffee cherries are transported to the farm plant. The transportation from the plantation plots to the primary processing plant is conducted by tractor as the plant is adjacent to the farm. Diesel consumption has already been modelled in the total energy balance (see previous chapter). The direct emissions arising from tractor transport are based on the EcoInvent database. The processes occurring in the farm plant consist of selection, washing, depulping, fermentation and sun-drying. The fermented coffee beans are then transported to the coffee mill which is located in Moshi town, in about 16 km distance from the farm.

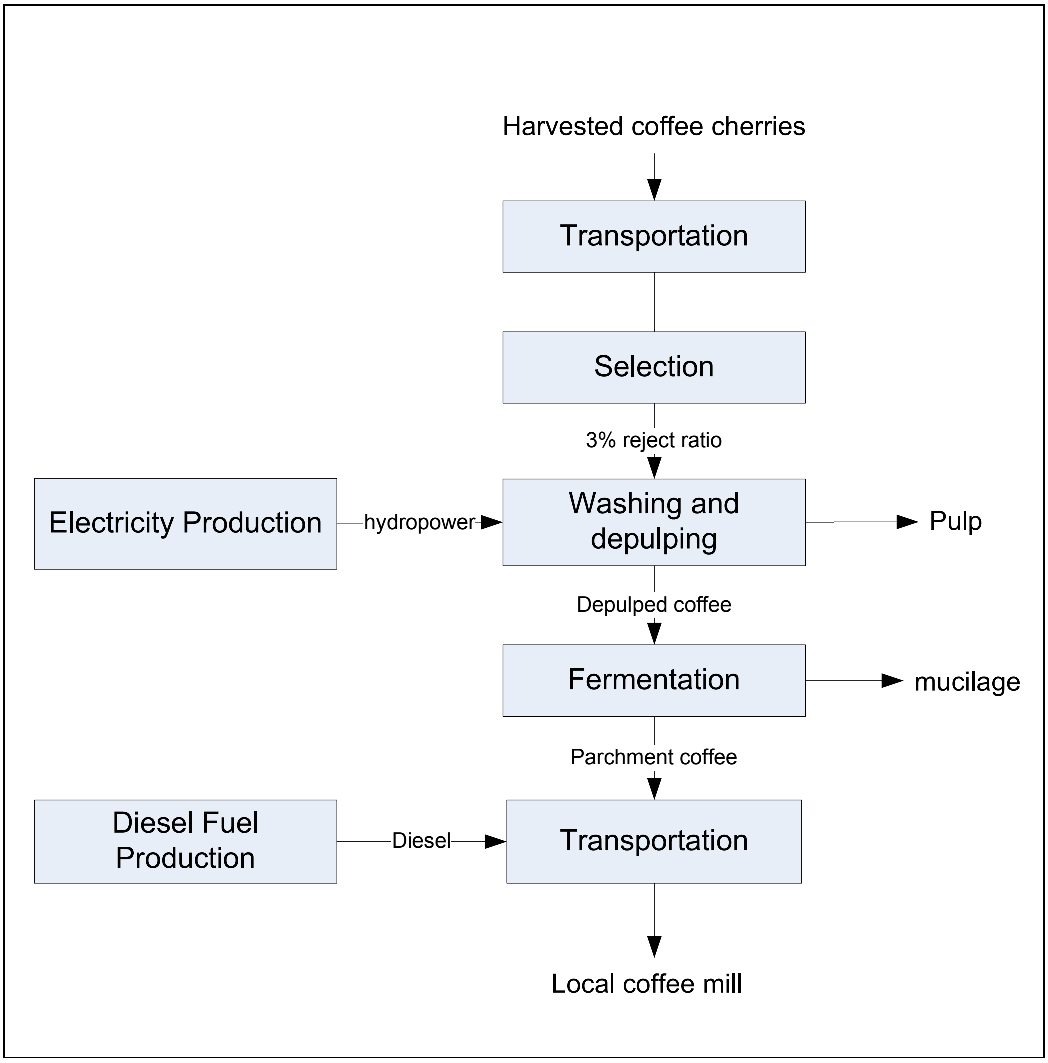


Figure 3: 6.1.2 Overview of the processes connected to the harvested coffee beans on the farm

Selection. About 3% of the coffee cherries are defective or unripe and float on the water. They are rejected through the siphon.

Washing and Depulping. The selected ripe coffee cherries are continually fed into the depulping machine, also called pulper, where a mesocarp layer adhering to the cherries is separated and removed. After pulping, the coffee beans are still surrounded by a slippery layer called mucilage. The mucilage contains mainly proteins, sugars and pectins. The composition of mucilage is showed in Table 3.

Table 3: Composition of mucilage [GTZ-PPP project 2002]

Composition of mucilage	Content [%]
Water	84.2
Protein	8.9
Sugars	
-Glucose (reducing)	2.5
-Sucrose (non reducing)	1.6
Pectin	1.0
Ash	0.7

Fermentation (wet fermentation[6]). To remove the mucilage, the freshly pulped beans are transferred into fermentation tanks and placed there for 36-72 hours. Whilst fermentation, the coffee beans are washed several times. The fermentation process bases on natural enzymatic changes, it does not need any external added microorganisms to induce but proceeds naturally. From the fermentation process certain main green house gases (GHG), like CO_2, CH_4 or N_2O could arise. Whereas the CO_2-emissions arising from the fermentation process do not have to be included according to PAS 2050 (Clause 5.4.2.3), the emissions of other green house gases like CH_4 shall be part of the analyses (PAS 2050, Clause 5.4.2.4). However, no data were available on the precise emissions of this process so that this aspect could not be considered. It might be worth to have a deeper look at the emissions of CH_4 and N_2O in further studies.

After fermenting, the mucilage is loosened from the beans so that it can be washed off with water.

Sun-drying. The fermented and washed coffee beans are dried naturally through sun and wind on tables, thus consuming no extra energy. Coffee beans in this stage are normally named parchment coffee[7].

Transportation to the mill: Subsequently, the dried parchment coffee is filled in sisal bags by hand and transported to the coffee mill by lorries with a maximum load of 7 tons. After the coffee beans reached the mill, the sisal bags are taken back to the farm and reused each year. The production of sisal bags is therefore excluded from this study.

6 Coffee cherries can be fermented in two ways: Wet fermentation is when coffee is fermented strictly under water, while dry fermentation is processed without added water. On the Machare farm the wet fermentation is used.

7 Parchment coffee means the green coffee bean contained in the parchment skin [ICO 2007].

With respect to the polluted wastewater, it mainly stems from the processing units where coffee is washed, depulped and fermented. For the treatment of the wastewater, a filtration system is implemented and water is fully re-circulated. The pulp is collected and used as organic fertiliser on the coffee plantation. The wastewater resulting from the fermentation process is being led into three soaking pits. After the solid residues, such as the mucilage layer surrounding the beans, has settled to the bottom of the pits, the wastewater is introduced into the wetland leaving the mucilage behind. Hence, no waste water emissions were modelled.

The pulp and the mucilage layer contain proteins, sugars and pectins and are applied to the coffee plantation as organic fertilizer. The therewith connected direct N_2O emissions from the soil are calculated following the same methodology as described in the previous chapter for fertilisers.

6.1.3 Modelling of the processes in the coffee mill

In the mill, parchment coffee is further stripped, polished and packaged, resulting in so called “green coffee”. The energy input encompasses electric energy and diesel. The mill is supplied by electric energy from the national grid in Tanzania (mainly hydropower). Because of the lack of data the production of diesel is modelled on the bases of data from EcoInvent for Europe. Green coffee beans leave approximate 20% of parchment layer and green skin behind which are transported to farms and used as organic fertilizers.

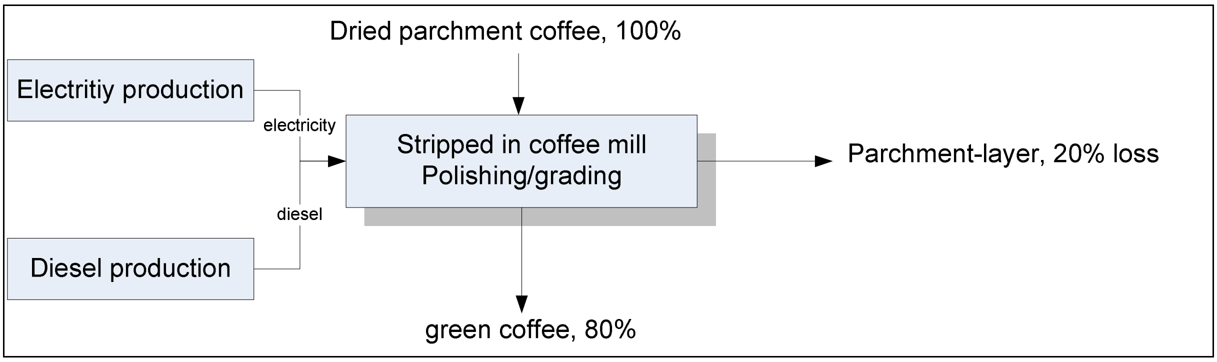


Figure 4: Overview of the processes in the mill

Packaging. At the mill the green coffee beans are filled in sisal bags.

For the overseas transport two ways of packaging are practised:

- Either: The coffee beans are transported in sisal bags that are put on Euro-pallets.
  => The packaging done at the mill is used for overseas transport.
- Or: The coffee beans are transported in container bags.
  => Sisal bags are emptied at the harbour into container bags for overseas transport. Sisal bags are brought back to the mill.

As the second option usually is used, it is considered in this study and described in the following sector.

With respect to the sisal bags, the production is excluded from the scope of this study as in most cases sisal bags have a long life-span and are reused several times.

6.1.4 Inland transportation and processing at harbour in Tanzania

This subsystem involves several operations including the transportation of green coffee from mill to the harbour, the production and transport processes of PP-woven bags (container bags) as well as the repackaging of the green coffee. The subsequent figure gives an overview on the different processes.

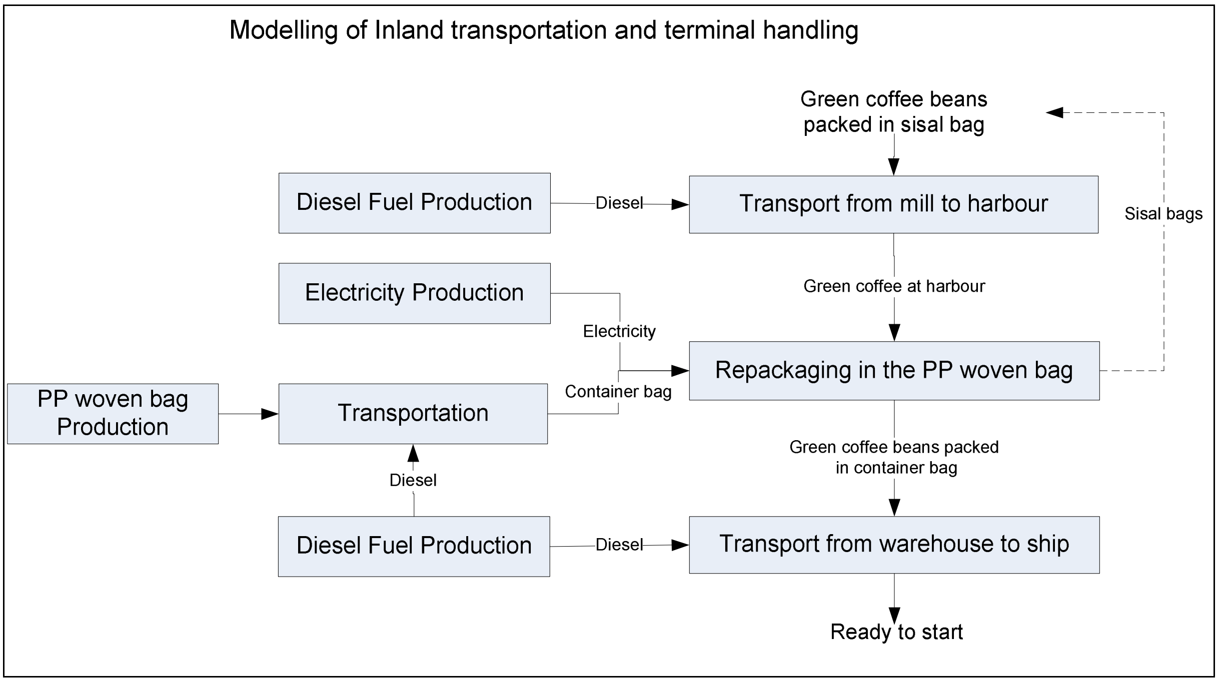


Figure 5: Modelling of inland transportation and terminal handling

The target harbour is located in *Dar es salaam*, 443 km away from Moshi. Green coffee is transported from the mill via lorry (maximum loading capacity 25 tons) into the *Dar es salaam* harbour. The transportation by lorry (gross weight of more than 34 tons) was modeled on the bases of Tremove 2.7. Furthermore, transports at the harbour from the warehouse to the ship are also taken into account. Two handling processes at the harbour are considered: The one is the emptying process from the truck. The other is the blowing process to put the green coffee into the container bag (45 minutes at 11 kW for each container).

As mentioned previously, container bags are made of a polypropylene woven fabric stitched together for reinforcement with strapping. The specific data are not available; however, IIT Delhi has already conducted an LCA study on PP-HDPE woven bag. It is assumed that energy inventory associated with PP-woven bag production is the same, i.e. 226.8 MJ/ton of packed product [Indian centre for plastics in the environment]. The transport distance from Tanga, where the container bags are manufactured, to *Dar es salaam* is 200 km (source: GoogleMap). Table 4 lists the used datasets.

Table 4: Overview on Inland transportation processes in Tanzania

Name of modules	Vehicles needed	Distance (one-way)	Datasets	Time / Geography	Dataset source
Transport from mill to harbour warehouse	3	443 km	LZ/SZ >34-40t	1980s/ pre-Euro	Tremove 2.7
Transport from warehouse to ship	3	1 km	LZ/SZ >34-40t	1980s/ pre-Euro	
Transport of container bag from plant to harbour	1	200 km	operation, van < 3,5t	2005 / RER	EcoInvent 2.0

6.2 Modelling of overseas transport

The modelling of the overseas transport comprises both the transport from Tanzania (*Dar es salaam* port) to Germany (*Hamburg* port) by cargo freighter and the transport from Hamburg port to the roasting plant located in Hamburg by lorry. As the overseas route was not clear at the time of calculation (transport of the coffee still lying ahead) two different shipment routes were modelled (see Table 5).

Table 5: Overview of processes concerning overseas transport

Variates	Route	Distance	Unit
Alternative I:	Dar Es Salaam - Salalah - HH; direct	13.580	km
Alternative II:	Dar Es Salaam - Salalah	3.209	km
	Salalah - Felixstowe/Antwerp	10.259	km
	Antwerp - HH	878	km

6.3 Modelling of the processes within Germany

6.3.1 Modelling of the processes in the roasting plant

After the green coffee beans have arrived in the roasting plant, they experience successively cleaning, roasting, cooling, grinding and packaging. In contrast to other coffee types there is no blending step in the whole processing as the rarity coffee is characterized by a single origin (one species, one coffee plantation). The Roasting process itself is the most important process in the roasting plant: On one hand concerning the quality of the coffee; on the other hand concerning the energy consumption. It should be pointed out that the supply of electric energy was modelled based on the general electric grid in Germany, although the roasting plant in Hamburg purchases electric energy from renewable sources certified by TÜV (technical monitoring association)[8]. The accordant hydro power plants are old plants that

[8] TÜV is an accredited German organisation working on the validation of the safety of products in order to protect humans and environment. TÜV has many subsidiaries that provide a wide range of services including certification.

already belong to the common electric grid in Germany. There is no evidence that the electricity originates from new hydro power plants - in general power plants not older then 12 years are named “new” - that would lead to an increase in the share of renewable energy in the electric grid in Germany and therefore would have an additional positive impact.

Consequently green electricity would only be modelled as renewable energy if the energy source contributes ultimately to fulfilling the additional environmental positive impact at the national/international level in the context of the PCF project[9].

Besides electric energy, natural gas for the roasting step and an inert gas such as nitrogen gas is applied into the package to help preserve the beans.

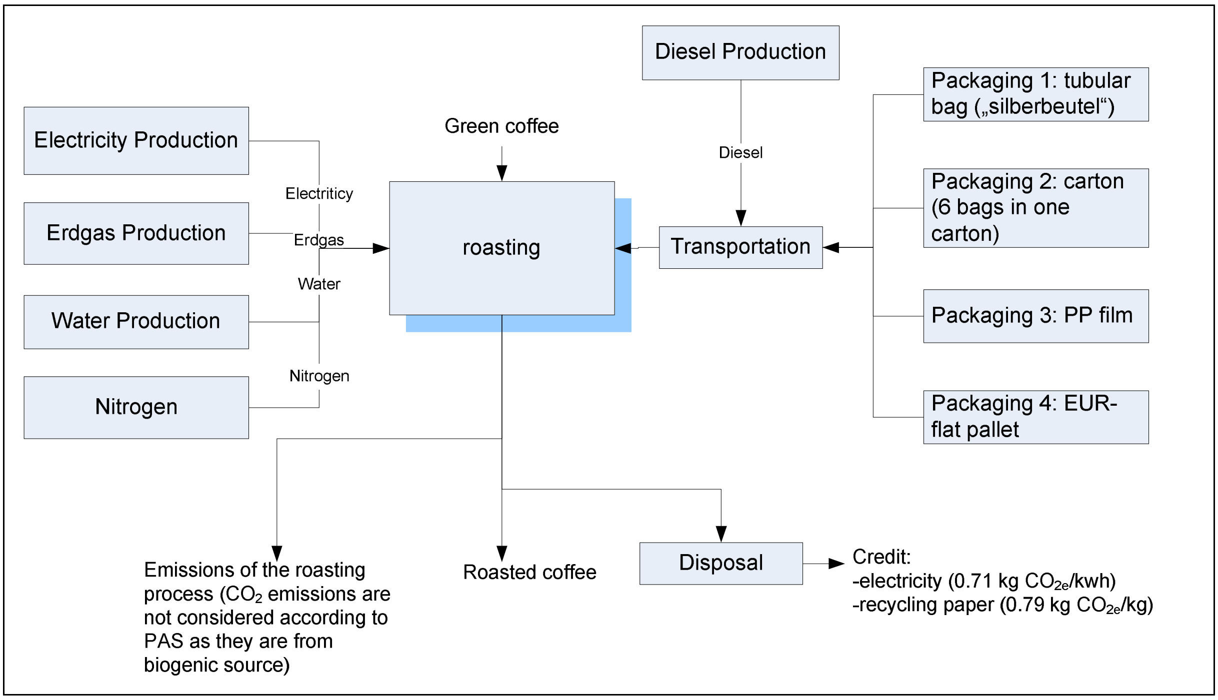


Figure 6: Overview on the processes in the roasting plant

The direct emissions in the roaster consist of roaster gas released from the beans while roasting and of emissions from natural gas combustion delivering thermal energy to the roaster. It is important to note that in accordance with PAS 2050, clause 5.4.2.3, the direct CO_2 emissions in the roaster gas are excluded from the assessment since they are arising from the coffee bean, a biogenic carbon source.

9 For further details on the green electricity please see PCF method paper later.

After processing, the roasted coffee[10] has to be packaged and transported further to the retailers. Packaging was investigated in detail including primary and secondary packaging for the handling and delivery of the coffee as well as consumer packaging[11]. The modules on the primary and secondary packaging include tubular bag, carton, Tesa™ strap, stretch wrap and Euro-pallet. The inventories of packaging materials are listed in Table .

Table 6: Overview on the input of packaging materials per 1000 kg of roasted coffee

	Name	Capacity of packed product	Materials	Amount	Unit
Packaging 1	tubular bag	1 kg of coffee beans / tubular bag	Sum	14,62	kg
			polyethylene, LDPE	*11,21*	*kg*
			Al-containing Polyester	*2,91*	*kg*
			Two component polyurethane adhesive	*0,50*	*kg*
Packaging 2	carton	6 kg of coffee packed in tubular bags / carton	corrugated board base paper, kraft liner	67,00	kg
Packaging 3	Tesa™ strap	1,5 g / carton	Polypropylene	0,25	kg
Packaging 4	EUR-flat pallet	378 kg of coffee packed in 63 cartons / pallet	wood	2,65	units
Packaging 5	stretch wrap	120 g / pallet	Polypropylene	0.32	kg

6.3.2 Distribution from the roasting plant to the Tchibo shops

Figure 7 shows how the roasted coffee is carried from the roasting plant to the single Tchibo shops store. Starting point is the roasting plant in Hamburg. The roasted coffee beans first are delivered to the centre Gallin by lorries (gross weight of 40 t). From there, the coffee is distributed to the three distribution points Bremen, Gernsheim and Neumarkt from where coffee is transported to Tchibo's affiliated shops.

[10] Roasted coffee means green coffee roasted to any degree and includes ground coffee [ICO 2007].

[11] Primary packaging is packaging designed to come into direct contact with the contents. Secondary packaging is packaging designed to contain one or more primary packages together with any protective materials where required. Consumer packaging is packaging constituting, with its contents, a sales unit to the final user or consumer at the point of retail [ISO/FDIS 21067].

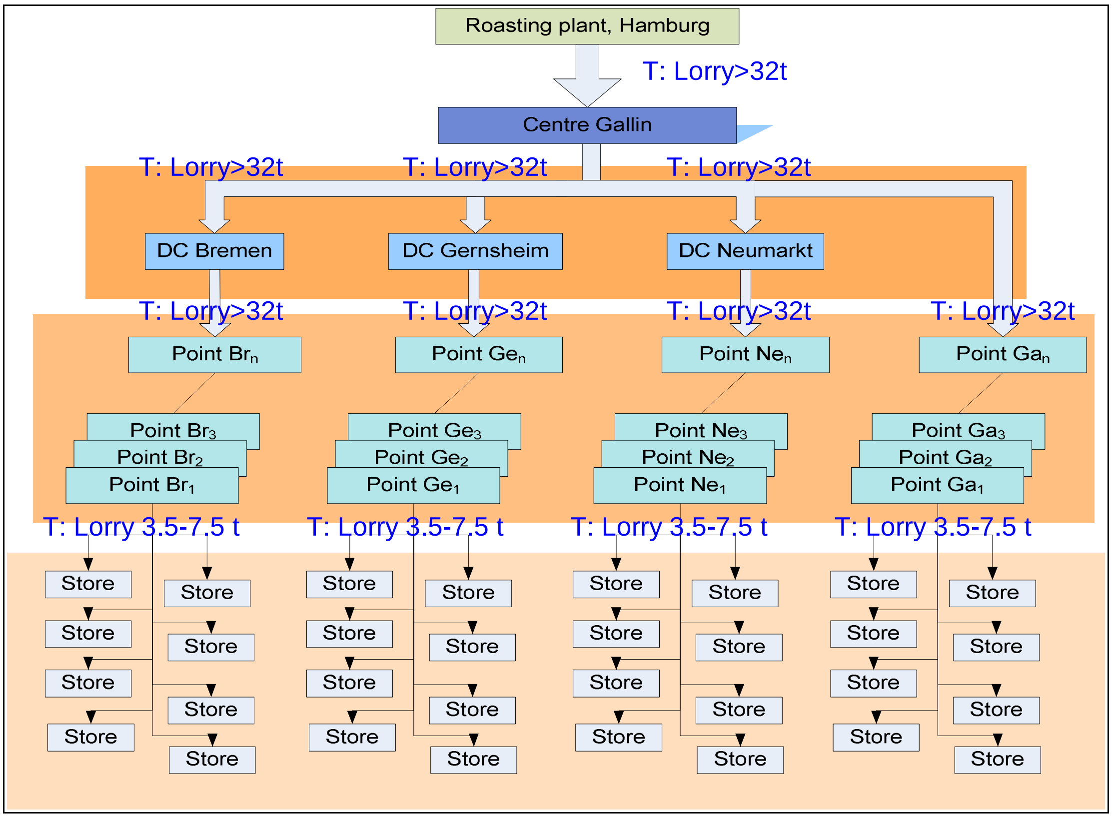


Figure 7: Overview on the distribution chain for the roasted coffee

6.3.3 Grinding in the Tchibo shops and packaging of final product

For the calculation it is assumed that the roasted coffee beans are ground in the Tchibo shops. The specific data base on the electric coffee grinder VTA 6S3 and were provided by Tchibo. Taken into account is the electric energy consumed by the grinder, i.e. 0.023 kWh of electricity required for 1 kg of coffee beans. The electricity production is modelled on the bases of the German electric grid. No coffee losses due to the grinding process were taken into account as they were assumed to be neglectable.

As for the packaging used for the final consumers, primary and secondary packaging[12] is concerned. Primary packaging includes a bag (16 g) and a clip (0,9 g) per 500 g of ground coffee. The bag consists of 64 % paper, 29 % parchment substitute, and 7 % paint/lacquer/glue. The clip consists of aluminium foil (gold), paper, wire (iron) and glue.

Secondary packaging is a shopping bag made from low density polyethylene (LDPE). It is accounted as an option depending on the consumers' wish. Hence, two scenarios were

12 Primary packaging refers to packaging designed to come into direct contact with the product. Secondary packaging refers to packaging designed to contain one or more primary packages together with any protective materials where required (ISO/FDIS 21067, 2007)

calculated: purchase including one shopping bag of 26 g resp. purchase without shopping bag.

6.4 Shopping Tour

For the modelling of the shopping to it has been assumed that not only one package of 500 g of coffee is purchased but a whole basket of commodities with an overall weight of 20 kg. The purchase is done by car with the calculation based on an average car.

Table 7: Overview on parameters assumed for the shopping tour

Shopping by car	Amount	Unit
An average 20 kg basket of commodities is purchased per one buying trip. Share of one package of 500 g coffee.	2.5	%
Average car (∅ 22% Diesel and 78% Otto)	5	km

The emission factors for the modelling of the car transport are taken from TREMOD.

6.5 Coffee Consumption

In order to take into account that consumers use different methods to prepare coffee, three different brewing methods were considered in the calculation. The first method is the so-called *French press*. Ground coffee is placed in a glass pot and hot water is poured into it. Then, an attached plunging device, which is tightly fitted to the glass pot, is pushed to the bottom of the pot, where the grounds are trapped. The second method used to brew coffee is defined as *Filter drip* in which coffee is brewed by means of an electronic drip machine and paper filter. Water is heated in a chamber of the machine and slowly dripped over the ground coffee. Brewed coffee is trapped in the normal glass pot and leaves the grounds in the filter. The third is an *automatic coffee machine.* An overview of modelling is shown in figure 8. Figure 9 gives an overview on the used inventories and data sources.

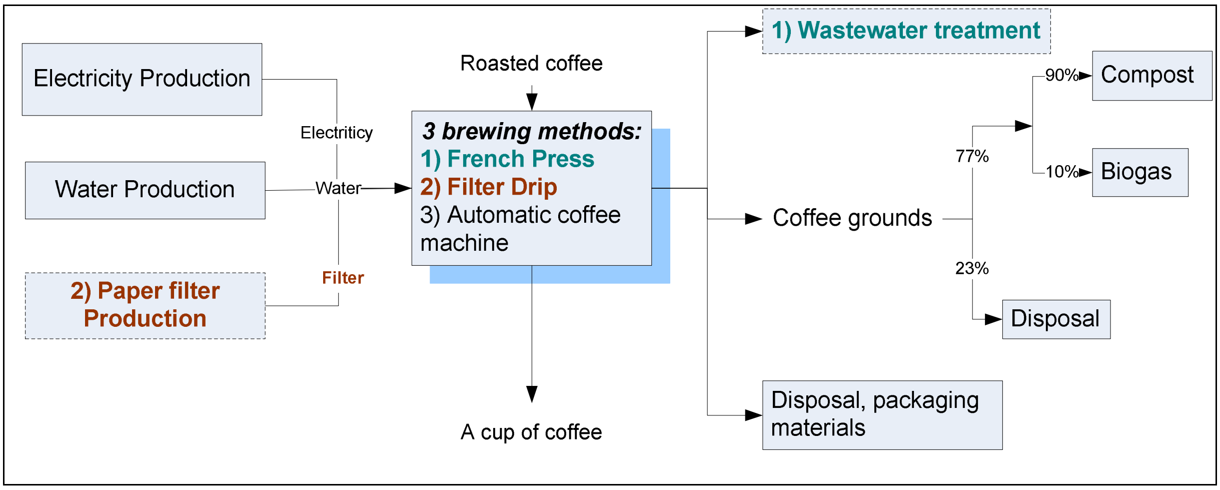


Figure 8: Modelling of the coffee consumption

Table 8 Inventories of the three brewing methods per cup of coffee

Brewing methods	Electricity [kwh]	Water [kg]	Additional materials used	Source
I: French press	0.0141	0.125	-	according to water boiler: Siemens TW 60101
II: Filter drip	0.0125	0.125	Filter:1.7 g/piece	Electricity consumption: Personal communication of Mr. Jürg Nipkow, ETH/SIA (2008) Filter: self-measured
III: Automatic coffee machine	0.085	0.125	-	toptten.ch (2008)[13]
Mix of methods used for the calculation (I: 9%+II: 75%+III: 16%)	0.0242	0.125	70% of paper filter used	Market survey study from Dialego AG (2008)

6.6 Recycling/Disposal

In the end-of life phase the following was taken into account: disposal of primary and secondary packaging and coffee grounds. A sensitivity analyses was performed concerning the coffee skin wastes occurring in the roasting plant. As they are sold as equivalent to wood pellets credits can be given for the substitution of other energy sources. The precise assumptions were the following:

[13] Topten.ch: 170kWh/2000cups*a = 0.085kWh/cup

Coffee skin from the roasting plant (sensitivity analyse):

For the generated thermal energy from the coffee skin pellets credits were given as a substitute for 1) wood pellets, 2) natural gas and 3) oil

Primary and secondary packaging

Tubular bag and PP film: disposal in incineration plant. For the generated electric energy credits are given.

Carton: 68 % recycling (credit), 32 % disposal

Euro-Pallet: excluded

Shopping bag and primary coffee bag: disposal in incineration plant. For the generated electric energy credits are given.

Coffee grounds

French press: waste water treatment. It was assumed that when using a French press coffee grounds are treated by washing them away into sewage.

Filter drip and automatic coffee machine: coffee grounds ->77% as biowaster (90% as compost and 10% as biogas); the remaining 23% come in an incineration plant

7 Presentation of Results (best guess)

7.1 Overview

The overall results of the case study show that one cup of rarity coffee is connected to a product carbon footprint of 59,12 g CO_{2e}. The following table shows the contribution of the single life cycle phases and the calculated min- / max-scenarios.

Table 9 Overview on the results in g CO_{2e} per cup of rarity coffee

Life cycle phase	best guess	min-Scenario	max-Scenario
Extraction of raw materials	32,99		
Production	3,93	3,45	3,93
Distribution	1,25		
Purchase	1,90		
Product use	17,90	9,82	60,10
Disposal	1,15	0,93	1,18

The subsequent figure illustrates in some more detail the processes in Tanzania and in Germany that are connected to the life cycle of one cup of rarity coffee.

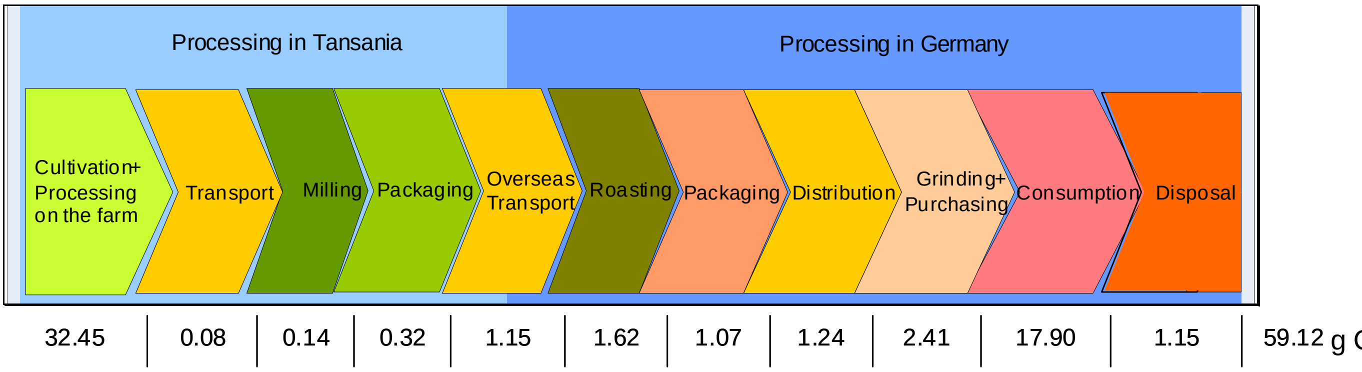


Figure 9: Overview on the life cycle phases and the CO_{2e} emissions of the different processes

Main emission drivers are the processes occurring at the farm including therewith connected upstream processes and the consumption phase. The following sections will describe in more detail the contributions of the different processes.

Uncertainties are described in the following sections that go more into detail on the single life cycle stages.

7.2 Extraction of Raw Materials

The processes in Tanzania providing the green coffee that is then roasted in Germany are herewith referred to as “extraction of raw materials”. The encompassed processes are listed in the subsequent table (illustrated also in the following figure), showing the results in g CO_{2e} per cup of rarity coffee. Two processes show up as main contributors: the upstream processes of the agrochemicals (fertilisers and pesticides), production and transport and the cultivation on the farm together contribute 96,29 % of the CO_{2e} emissions. The production of electricity as well as diesel and petrol are with an overall share of 1,95 % much less important.

Table 60 Overview on the CO_{2e} emissions connected to the processes in Tanzania [in g CO_{2e} per cup of rarity coffee]

Process	**Amount [g CO_{2e}/cup of rarity coffee]**	**Share [percent]**
Cultivation	5,65	17,14%
Energy production	0,64	1,95%
Application of agrochemicals	0,04	0,12%
Agrochemicals, production and transport	26,11	79,16%
Transport, farm ⇒ plant	0,01	0,02%
Transport, farm ⇒ mill	0,08	0,23%
Processes in the mill	0,14	0,42%
Transport, mill ⇒ harbour	0,32	0,97%
Total	**32,99**	**100,00%**

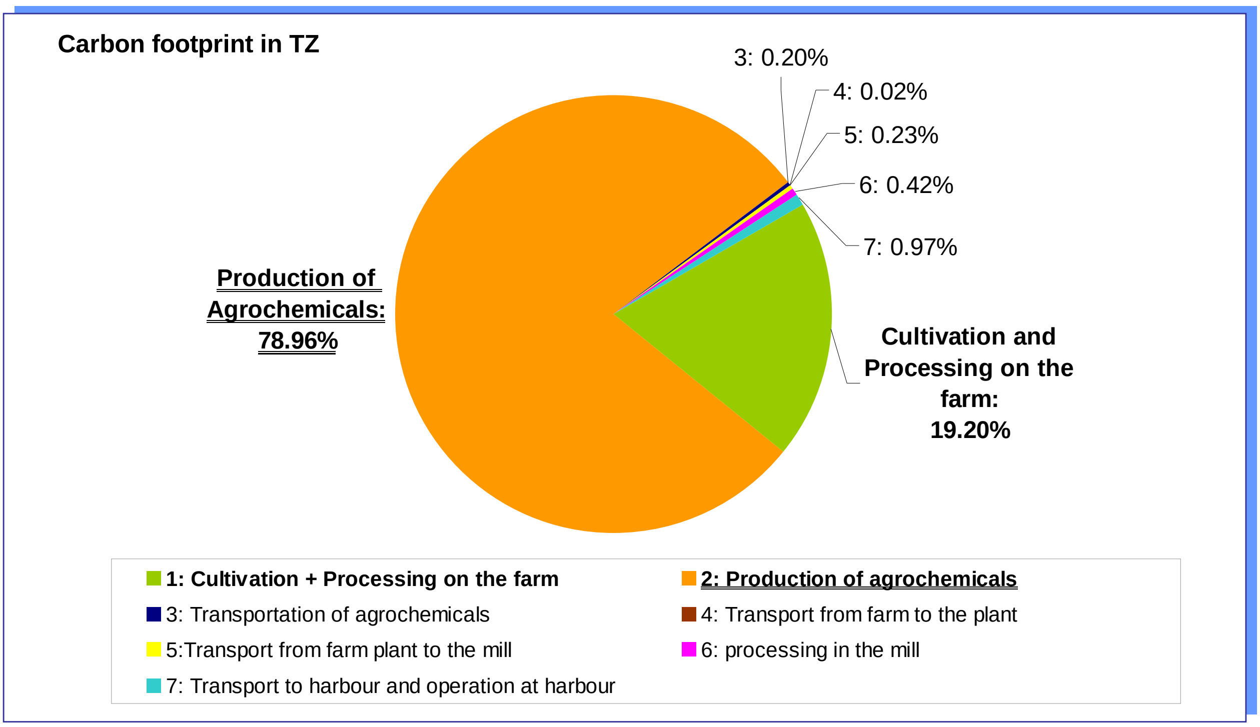


Figure 10:Carbon Footprint in Tanzania

Main emission driver is the production of agrochemicals with a contribution of 79 percent referring to the processes in Tanzania resp. 44 % referring to the overall emissions of CO2e connected to one cup of rarity coffee.

Uncertainties mainly concern the amount of consumed electric energy that seemed to be relatively low. On the other hand, due to the dominance of hydro power no significant influence on the result is expected.

7.3 Production

The overall CO_{2e} emissions connected to the production of one cup of rarity coffee – encompassing the overseas transport and the processes in the roasting plant including the packaging – amount to 3,93 g CO_{2e}. / cup of rarity coffee.

The overseas transport only contributes with 1,15 g of CO2e to the overall Carbon Footprint of one cup of rarity coffee.

Main emission drivers: Both, electricity supply and provision of thermal energy have a significant share of together 65,5 % to the overall CO_{2e} emissions in the roasting plant (including packaging).

In accordance with PAS 2050, the direct CO_{2e} emissions of the roasting process are not included as they originate from a biogenic source. The contribution due to the use of water is very small but not – as it might seem from the figure.- zero.

Uncertainties concern mainly the precise energy demand and emissions of the Tchibo Privat Kaffee Rarity Machare in the roasting plant. As the coffee had not been roasted at the time of the performance of this study, the data of the roasting plant had to refer to data collected earlier. Still, no significant influence on the result is expected, especially as the overall share of the roasting process is rather small. The same is valid for the uncertainties concerning the overseas transport, which – like the roasting process - was not determined at the time of the study.

7.4 Distribution

The distribution only contributes with 1,45 g CO_{2e} or 2,1 % to the overall CO_{2e} emissions of one cup of rarity coffee.

Uncertainties concern the distribution structure (e.g. number and place of distribution centres) that is subject of change.

7.5 Shopping Tour

The shopping tour only contributes with 1,9 g CO_{2e} or 3,2 % to the overall CO_{2e} emissions of one cup of rarity coffee.

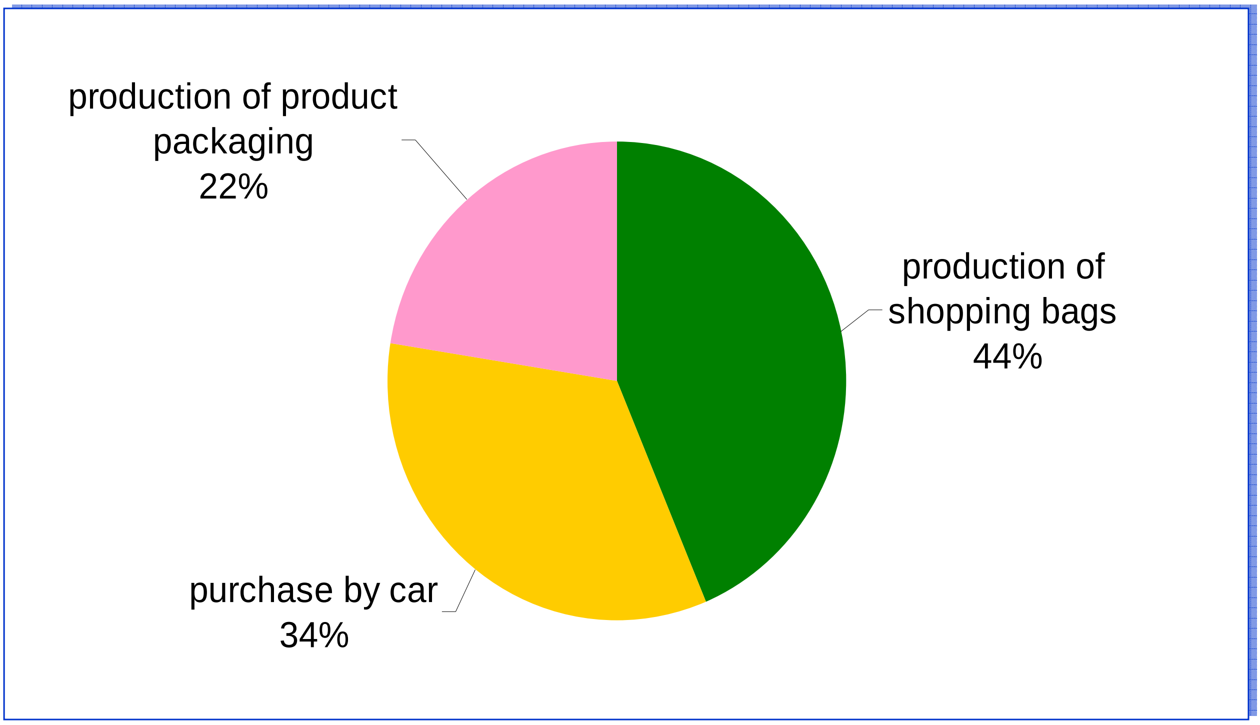


Figure 11: Share of the different processes connected to the shopping (without grinding in the store)

Main emission drivers are the shopping bag and the purchase by car.

Uncertainties concern mainly the purchase by car as purchase behaviour may vary significantly and no specific data on the purchase behaviour of Tchibo shop customers was available. As a consequence the contribution of this process might be rather higher (e.g. one shopping tour for one package of coffee) or lower (e.g. shopping by bike). The second point is the shopping bag that might not be taken by every customer.

7.6 Product Use

With the contribution of 17,9 g CO_{2e} per cup of rarity coffee or 30,3 % the preparation of coffee by the consumer plays a crucial role in the carbon footprint of the Tchibo Privat Kaffee Rarity Machare.

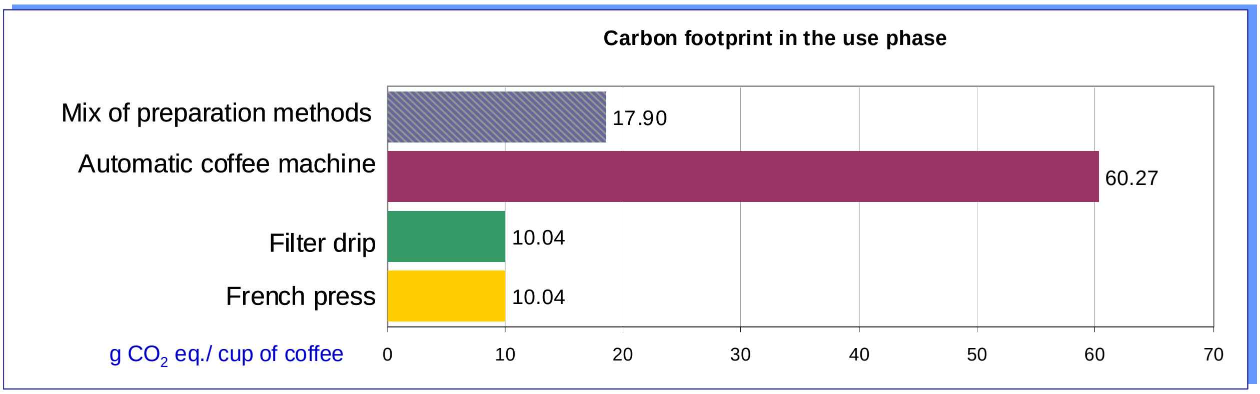


Figure 12: Overview on the CO_{2e} emissions from product use

Main emission driver is the preparation of coffee by an automatic coffee machine.

Uncertainties concern the real mix of different preparation methods among Tchibo customers. As no data were available an assumption was made on the bases of a general survey on coffee preparation from 2008. Preparation of coffee with pad machines was left out as being not relevant for rarity coffee.

7.7 Disposal/Recycling

The disposal of coffee contributes with 1,15 g CO_{2e} resp. 1,9% to the overall CO_{2e} emission of one cup of rarity coffee.

The subsequent figure shows the contribution of the disposal of coffee grounds.

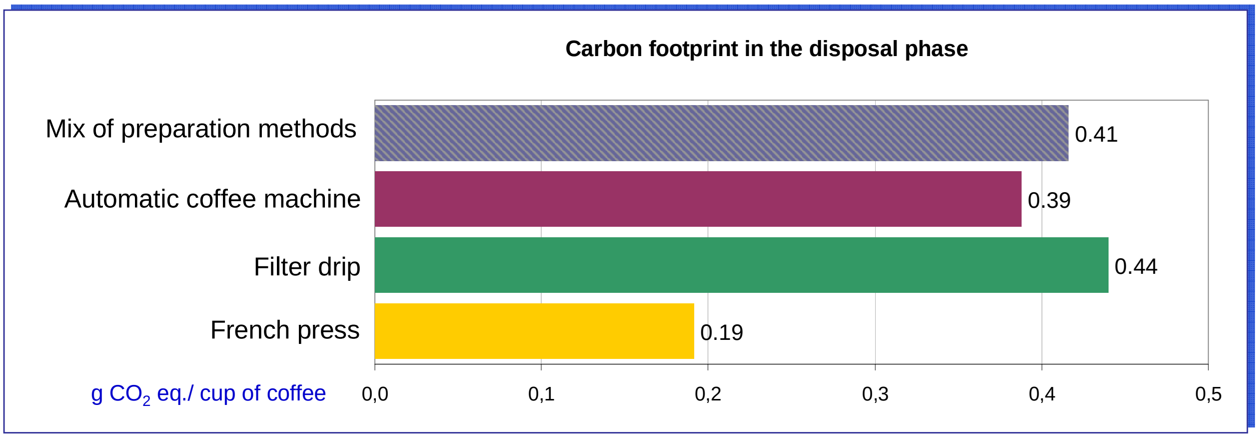


Figure 13: Overview on the CO_{2e} emissions from the disposal of the coffee grounds depending on the preparation method

8 Assessment of the Results

8.1 Sensitivity Analysis

Basing on the modelling and the available data three sensitivity scenario were calculated (see subsequent table for illustration).

Sensitivity Scenario 1 represents the best case and bases on the overseas transport by three ships, a shopping tour by bike, coffee preparation with French press and credits from recycling.

Sensitivity Scenario 4 represents the worst case and basically is differentiated from the base case by the preparation method which is assumed to be with the automatic coffee machine.

	Base case	Scenario 1: the best case	Scenario 2	Scenario 3	Scenario 4: the worst case
Overseas transport	By one ship	By three ships	By three ships	By one ship	By one ship
Purchase trip	By car, 5 km, part of total 20 kg purchased	By foot or bicycle	By car, 5 km, part of 20 kg purchased in total	By car, 5 km, part of 20 kg purchased in total	By car, 5 km, part of 20 kg purchased in total
Shopping bag	With	Without	With	With	With
Brewing methods	Cosumption mixed (I:9%+II:75%+ III:16%)	Consumption I: French press	Consumption I: French press	Consumption II: Filter drip	Consumption III: automatic coffee machine
Credits	Not considered	1. Electric energy from incineration 2. Recycling paper form carton 3. Coffee pellet:thermal energy as a substitute for oil	1. Electric energy from incineration 2. Recycling paper form carton 3. Coffee pellet:thermal energy as a substitute for natural gas	1. Electric energy from incineration 2. Recycling paper form carton 3. Coffee pellet: thermal energy as a substitute for wood	Not considered
g CO_{2e} / cup of coffee	***59.12***	***47.75***	***50.37***	***51.17***	***101.88***

Figure 114: Overview on the sensitivity analyses that were performed

As a consequence it can be concluded that - at this point of knowledge about coffee cultivation – the most important key processes to be influenced/changed is the coffee preparation. Still it is clear that the coffee cultivation modelled in this study is of extraordinary good standard and conventional cultivation methods are connected with a different carbon footprint. Further studies should have a closer look into that.

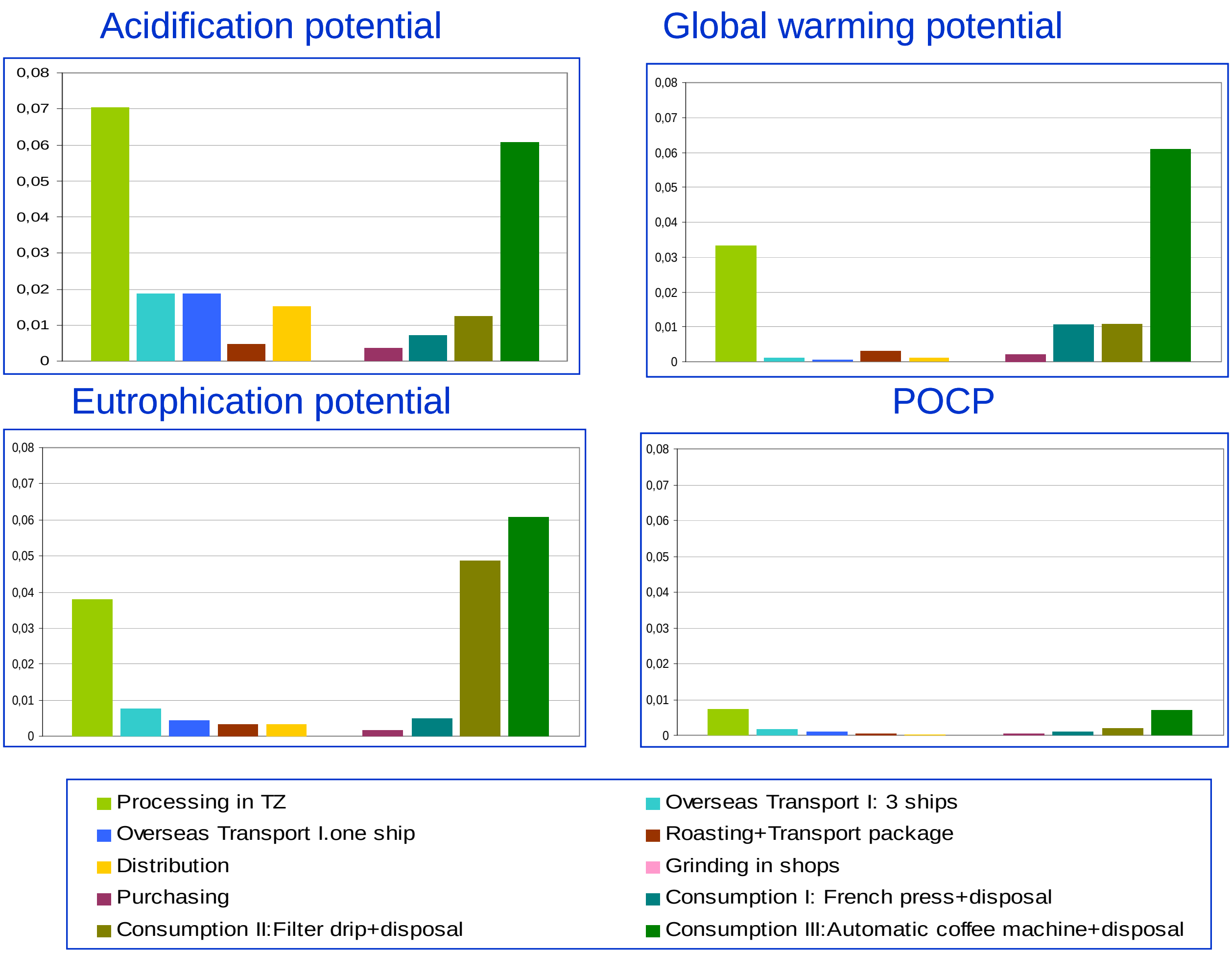
8.2 Handling of other Environmental Impact Categories

8.2.1 Analysis of other Environmental Impact Categories

In the following it is illustrated to what extent other environmental impact categories as green house gases / global warming like acidification, eutrophication and photochemical ozone creation (POCP) contribute to the impacts of the life cycle of one cup of rarity coffee.

Focus of these analyses is the question whether one would draw different conclusions when including these other environmental impact categories.

This is not the case as one can see that both the processes in Tanzania as well as the preparation of coffee by the consumer contribute by far most to the overall CO_{2e} emissions. That way showing the same result as in the impact category global warming. One difference can be identified: Concerning the impact category acidification, transports (overseas transport as well as the distribution in Germany) play a more prominent role then when looking at the global warming potential.



9 Interpretation and Perspectives

9.1 Challenges of the Case Study

The supply chain of coffee, especially in bulk business, is very complex. In consequence the backtracking of coffee products to their origin is in many cases not possible.

Certified coffees with their transparent supply chains enable traceability, however, data regarding farming and cultivation are frequently not available.

By contrast, due to the high quantity and quality of the data of the “Tchibo Privat Kaffee Rarity Machare”, it is possible to give a very detailed description of the supply chain.

Data from suppliers of sales packaging and of additives for the roasting process were partly difficult to collect.

9.2 Identification and Assessment for Further Reduction Options of the PCF

Further reductions seem to be accessible - subject to impacts on crop yields, soil fertility etc. - in the hot spots

- Coffee cultivation and
- Coffee preparation by consumers.

Regarding climate protection the coffee cultivation of Tchibo Privat Kaffee Rarity Machare can be estimated as extensively optimized. In order to identify further possible potentials for optimization, it is necessary to conduct complementary studies.

Any options for communication measures towards consumers regarding the reduction potential in the preparation phase have to be considered thoroughly (please also see Chapter 9.3).

9.3 Measures under Consideration to Further Reduce the PCF

Identification of further optional reduction potentials require thorough analyses of

- other methods of coffee cultivation (irrigation, conventional cultivation and other sustainable cultivation methods) as well as methods of green coffee processing (dry and wet processing, sun drying and oven drying); in order to classify the case study results;
- correct proportions of crop yields, conservation of soil fertility and amount of used agrochemicals; and therefore the most sustainable and climate-optimised cultivation method.

Moreover, a further reduction potential can be found in coffee preparation method. Precondition of any communication measures towards consumers is the consolidation of all PCF results, especially regarding other preparation methods which have not been considered in this study. Additionally, the modality and the contents of any communication have to be designed and harmonized.

Another topic which requires further studies is the compensation potential of shaded polyculture e.g. according to the standards of the Rainforest Alliance. This could mean the chance to compensate the GHG emissions directly inside of supply chains.

9.4 Product Carbon Footprinting at Tchibo in the Future

We will put PCF in the wider company sustainability strategy; with a special focus on climate change. This includes the following measures:

- Build-Up internal know-how on climate impacts of the food sector.
- Increase sourcing of coffee which will be cultivated in line with best practices.
- Identify further options how to reduce the carbon footprint in the supply chain.
- Assess costs and benefits (including communicational) of compensation especially as coffee is a tree.

10 Recommendations

10.1 International Methods for Calculation and Assessment of Product Carbon Footprints

- A very important recommendation is to factor the use phase (preparation) as well as the pre-processes, especially the production of agrochemicals, into the PCF methodology.

10.2 Proposals for Product Specific Definitions and Rules (EPD, PCR)

- Designing a harmonized standard for compensation methods inside of the coffee supply chain (e.g. by shade trees) seems to be very useful.
- For other aspects please see also Chapter 10.1.

10.3 Reporting, Communication and Claims of Reductions to Customers and Consumers

- The transparent communication of the applied scope and methods is indispensible for the PCF credibility.
- The applied cultivation method and its climate compatibility should be mentioned without leaving other relevant environmental impacts unmentioned.

11 References

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12 Abbreviations

C	Carbon
GEMIS	Globales Emissions-Modell Integrierter Systeme
EcoInvent	
CH	Switzerland
DE	Germany
RER	Europe
TZ	Tanzania, United Republic Of
ICO	International Coffee Organisation
IIT	Indian Institute of Technolgoy, Delhi
Vkm	vehicle kilometre
Tkm	ton kilometre
ha	hectare
kg	kilogram
Eq.	equivalent
CAN	calcium ammonium nitrate
NPK	Nitrogen, phosphorus, and potassium
DAP	diammonium phosphate
PP	polypropylene
TÜV	Technischer Überwachungs-Verein (in German); Technical Monitoring Association (in English)
BUWAL	Bundesamt für Umwelt, Wald und Landschaft, Bern, Switzerland

13 Documentation of the Data

13.1.1 Processes on the farm

					Data index			
Data Module (Output)	**Processes covered**	**Time related coverage**	**Geographical specificity**	**Technological specificity**	**Place of reference: in-house (I), literature (L), other (O and specify)**	**Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part**	**Measured (M); calculated (C); estimated (E)**	**Data source**
Diesel Production	diesel, at regional storage	2000	Europe (Surveys mainly for DE and CH)	Distribution of petroleum products.	L	A	C	EcoInvent 2.0
Petrol production	petrol, unleaded, at regional storage	2000	Europe (Surveys mainly for DE and CH)	Distribution of petroleum products.	L	A	C	EcoInvent 2.0
Hydropower in Tanzania	hydro-dam-Tan-Ruhudji	2008	Tanzania	Generic hydro-electric powerplant-dam + reservoir	L	A	?	Gemis 4.42 2000

Selecron (profenofos), Diazinon, production	organophosphorus-compounds, at regional storehouse	1987	Europe	The manufacturing process was modelled on information given about the method of manufacture in the patents or, in case of pesticides which are no longer subject to patent protection, on detailed literature on the production process.	L	A	C	EcoInvent 2.0
Decis, Keshet (deltamethrin)	pyretroid-compounds, at regional storehouse	1987	Europe	s.o	L	A	C	EcoInvent 2.0
Thionex (endosulfan)	pesticide unspecified, at regional storehouse	1987	Europe	s.o	L	A	C	EcoInvent 2.0
herbicide:Mamba	glyphosate, at regional storehouse	1987	Europe	s.o	L	A	C	EcoInvent 2.0
Bayfolan: Nitrogen 11%, Phosphoric Acid 8%, Potash 6%	ammonium nitrate phosphate, as N, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0
	ammonium nitrate phosphate, as P2O5, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0
	potassium sulphate, as K2O, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0
Multi-K	potassium nitrate, as K2O, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0

Phosphoric Acid	phosphoric acid, fertiliser grade, 70% in H2O, at plant	1999-12	Global	Data refers only on production of wet-phosphoric acid by the dihydrate process in Florida and Morocco. No further technologies included.	L	A	C	EcoInvent 2.0
Urea	urea, as N, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0
Zinc Oxide	zinc oxide, at plant	2007	Europe	Production out of secondary zinc materials by mean of the indirect (or French) way. The emissions to air (1 wt.% of raw material input) and water were estimated using mass balance.	L	A	C	EcoInvent 2.0
Magnesium Sulph.	magnesium sulphate, at plant	2000	Europe	Data approximated with data from lime mining, crushing and milling.	L	A	C	EcoInvent 2.0

Sequestrene (EDDHA NaFe)	iron (III) chloride, 40% in H2O, at plant	2001-12	Switzerland (Data valid for production processes used in Switzerland. Various processes with location RER used.)	Inventory refers to technology used for production in Switzerland. Excess chlorine can be used in NaOCl production and therfor no chlorine emissions to air occur.	L	A	C	EcoInvent 2.0
Solubor	boric oxide, at plant	2006	Global	Fusion of boric oxide	L	A	C	EcoInvent 2.0
Copper-containing inorganic pesticides	copper oxide, at plant	2000	Europe	Production from copper(II)oxide by hyrdometallurgy	L	A	C	EcoInvent 2.0
Alto-cyproconazol	cyclic N-compounds, at regional storehouse	1987	Europe		L	A	C	EcoInvent 2.0
Phosphite	sodium phosphate, at plant	1994	Europe	average technology for the examined area / time	L	A	C	EcoInvent 2.0
Thiovit	secondary sulphur, at refinery	2000	Europe	Assumption for average technology.	L	A	C	EcoInvent 2.0
MOP (Refers to 1 kg K2O, resp. 1.67 kg potassium chloride with a K2O-content of 60.0%)	potassium chloride, as K2O, at regional storehouse	2000	Europe	The potash salts stem from underground mines. Three different technologies are used to concentrate the salt: solution in hot water, flotation and electrostatic separation.	L	A	C	EcoInvent 2.0

Dolmax	phosphate rock, as P2O5, beneficiated, dry, at plant	2001-12	MA. Assumption for production in Morocco based mainly on data from Florida. Some data from Moroccan mines. Various processes with location RER used.	U.S. technology for dry rock or dried wet rock processing. Average technology mix modelled. No specific age of technology modelled	L	A	C	EcoInvent 2.0
NPK (19-19-19)	potassium chloride, as K2O, at regional storehouse				L	A	C	EcoInvent 2.0
	ammonium nitrate, as N, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0
	triple superphosphate, as P2O5, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0
CAN	calcium ammonium nitrate, as N, at regional storehouse				L	A	C	EcoInvent 2.0
DAP	diammonium phosphate, as N, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0
	urea, as N, at regional storehouse	1999	Europe		L	A	C	EcoInvent 2.0

13.1.2 Processing in the local mill in Tanzania

					Data index			
Data Module (Output)	Processes covered	Time related coverage	Geographical specificity	Technological specificity	Place of reference: in-house (I), literature (L), other (O and specify)	Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part	Measured (M); calculated (C); estimated (E)	Data source
Production of container bag	polypropylene, granulate, at plant	2001	Europe	polymerization out of propylene	L	A	C	EcoInvent 2.0
	extrusion, plastic film	1997	Europe	present technologies	L	A	C	EcoInvent 2.0

13.1.3 Processing in the roasting plant

					Data index			
Data Module (Output)	Processes covered	Time related coverage	Geographical specificity	Technological specificity	Place of reference: in-house (I), literature (L), other (O and specify)	Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part	Measured (M); calculated (C); estimated (E)	Data source
electricity	electricity, medium voltage, at grid	2000	Germany	Average technology used to transmit and distribute electricity. Includes underground and overhead lines, as well as air-, vacuum- and SF6-insulated high-to-medium voltage switching stations. Electricity production according to related datasets	L	A	C	EcoInvent 2.0
water	tap water, at user	2000	Switzerland	Example of a water works in CH.	L	A	C	EcoInvent 2.0
Natural gas	natural gas, burned in industrial furnace >100kW	2000	Europe	Fan burners on market (modulating or non-modulating, non-condensing)	L	A	C	EcoInvent 2.0

N2	Production	1999	Deutschland		L	A	C	Gabi 4

13.1.4 Transport packaging

					Data index			
Data Module (Output)	Processes covered	Time related coverage	Geographical specificity	Technological specificity	Place of reference: in-house (I), literature (L), other (O and specify)	Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part	Data Module (Output)	Processes covered
Euro-Pallet	EUR-flat pallet	2002	Europe	Standard composition of materials (Module includes only materials (no production process) and should only be used for the packing and transportation of products.)	L	A	C	EcoInvent 2.0
Carton	1.1 corrugated board base paper, kraftliner, at plant	2005	Europe	Average of present used technology	L	A	C	EcoInvent 2.0
	1.2 Production of carton board boxes	1998	Switzerland		L	A	C	Umberto library: BUWAL (1998): Schriftenreihe Umwelt 250 / II, Ökoinventare für Verpackungen

								Band II, BUWAL
Tubular bag	1.1polyethylene, LDPE, granulate, at plant	2001	Europe	polymerization out of ethylene at high pressure and high temperature	L	A	C	EcoInvent 2.0
	1.2 polyethylene terephthalate, granulate, amorphous, at plant	2000	Europe	PET production out of PTA and ethylene gylcol	L	A	C	EcoInvent 2.0
	1.3.aluminium, production mix, at plant	2002	Europe	Mix	L	A	C	EcoInvent 2.0
	2 extrusion, plastic film				L	A	C	EcoInvent 2.0
adhesives	polyurethane, flexible foam, at plant	1997	Europe	Present technology used in Europe. Transport and infrastructure – average values added.	L	A	C	EcoInvent 2.0

13.1.5 Packaging of final product

					Data index			
Data Module (Output)	Processes covered	Time related coverage	Geographical specificity	Technological specificity	Place of reference: in-house (I), literature (L), other (O and specify)	Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part	Measured (M); calculated (C); estimated (E)	Data source
Shopping bag	polyethylene, LDPE, granulate, at plant	2001	Europe	polymerization out of ethylene at high pressure and high temperature	L	A	C	EcoInvent 2.0
	extrusion, plastic film	1997	Europe	present technologies	L	A	C	EcoInvent 2.0
Primary coffee bag	kraft paper, bleached, at plant	1993	Europe	Technology of one producer at the beginning of the 90's	L	A	C	EcoInvent 2.0
	polyurethane, flexible foam, at plant	1997	Europe	Present technology used in Europe. Transport and infrastructure - average values added.	L	A	C	EcoInvent 2.0
	electricity, medium voltage, at grid	2004	German	Average technology used to transmit and distribute electricity. Includes underground and overhead lines, as well as air-, vacuum- and SF6-insulated high-to-medium voltage switching stations.	L	A	C	EcoInvent 2.0

				Electricity production according to related datasets				
Clip	kraft paper, unbleached, at plant	Europe	2000	Average of present used technology	L	A	C	EcoInvent 2.0
	milling, cast iron, small parts	Europe	2007	Average technology	L	A	C	EcoInvent 2.0

13.1.6 All Transportation involved

XXX will be added

					Data index			
Data Module (Output)	Processes covered	Time related coverage	Geographical specificity	Technological specificity	Place of reference: in-house (I), literature (L), other (O and specify)	Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part	Measured (M); calculated (C); estimated (E)	Data source

13.1.7 Consumption

					Data index			
Data Module (Output)	Processes covered	Time related coverage	Geographical specificity	Technological specificity	Place of reference: in-house (I), literature (L), other (O and specify)	Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part	Measured (M); calculated (C); estimated (E)	Data source
Electricity	electricity, low voltage, at grid	2004	German	Average technology used to distribute electricity. Includes underground and overhead lines, as well as air- and SF6-insulated medium-to-low voltage switching stations. Electricity production according to related datasets	L	A	C	EcoInvent 2.0
water	tap water, at user	2000	Europe	Example of a water works in CH.	L	A	C	EcoInvent 2.0
Paper filter	sulphate pulp, average, at regional storage	2000	Europe	Average situation	L	A	C	EcoInvent 2.0

13.1.8 Disposal/Recycling

					Data index			
Data Module (Output)	Processes covered	Time related coverage	Geographical specificity	Technological specificity	Place of reference: in-house (I), literature (L), other (O and specify)	Single value (S); aggregated value (A) and specify the percentage or absolute amount of each part	Measured (M); calculated (C); estimated (E)	Data source
Coffee grounds: biogas	disposal, biowaste, to anaerobic digestion	2004	Switzerland	Thermophile, single stage digestion with post composting.	L	A	C	EcoInvent 2.0
Coffee grounds: compost	digested matter, application in agriculture	2004	Switzerland	Thermophile, single stage digestion with post composting.	L	A	C	EcoInvent 2.0
Coffee grounds to incineration plant	MVA mittlerer Standard	1999	Deutschland	Die in dieser Transition verwendete Anlage ist mit einer Rostfeuerung als Feuerungskessel ausgestattet wie er dem üblichen Stand der Technik repräsentiert.	L	A	C	Umberto 4,5

	treatment, sewage, to wastewater treatment, class 3	2000-12	Switzerland (Specific to the technology mix encountered in Switzerland in 2000. Well applicable to modern treatment practices in Europe, North America or Japan.)	Three stage wastewater treatment (mechanical, biological, chemical) including sludge digestion (fermentation) according to the average technology in Switzerland	L	A	C	EcoInvent 2.0