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Life cycle assessment of drinking Darjeeling tea

Conventional and organic Darjeeling tea

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1 Life Cycle Assessment (LCA) Methodology

The life cycle assessment (LCA) – sometimes also called ecobalance – is a method to assess the environmental impacts of a product[1]. The LCA is based on a perspective encompassing the whole life cycle. Hence, the environmental impacts of a product are evaluated from cradle to grave, which means from the resource extraction up to the disposal of the product and also the production wastes.

The International Organization for Standardization (ISO) has standardised the general procedure of conducting an LCA in ISO 14040 (International Organization for Standardization (ISO) 2006a) and ISO 14044 (International Organization for Standardization (ISO) 2006b).

A LCA consists of four phases (Fig. 1.1):

1) Goal and Scope Definition
2) Inventory Analysis
3) Impact Assessment
4) Interpretation

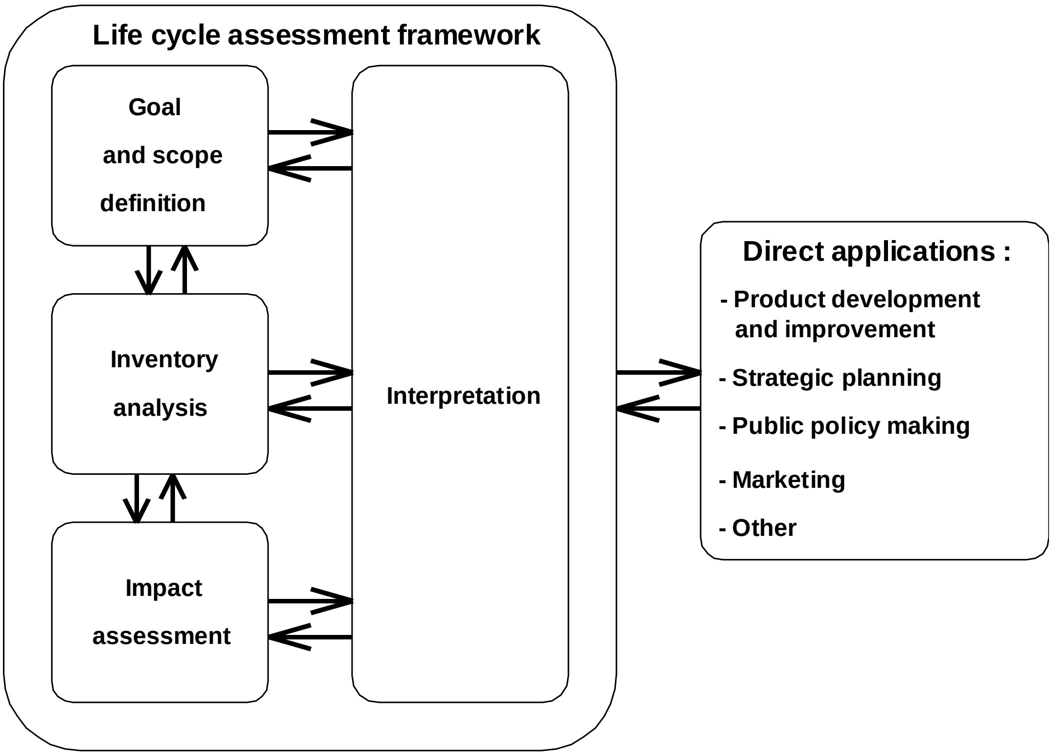

Fig. 1.1 Components of a life cycle assessment (LCA) according to International Organization for Standardization

The *Goal Definition* (phase 1) covers the description of the object of investigation. The environmental aspects to be considered in the interpretation are also defined here. The *Scope Definition* includes the way of modelling the object of investigation, the identification as well as the description of the processes of importance towards the object of investigation. The functional unit, which determines the base for the comparison, is defined here.

[1] The term product also encompasses services

The direct environmental impacts[2], the amount of semi-finished products, auxiliary materials and energy of the processes involved in the life cycle are determined and inventoried in the *Inventory Analysis* (phase 2). This data is set in relation to the object of investigation, i.e. the functional unit. The final outcome consists of the cumulative resource demands and emissions of pollutants.

The Inventory Analysis provides the basis for the *Impact Assessment* (phase 3). Applying current valuation methods, e.g. eco-indicator, ecological scarcity or CML, to the inventory results in indicator values that are used and referred to in the interpretation.

The results of the inventory analysis and the impact assessment are analysed and commented in the *Interpretation* (phase 4) according to the initially defined goal and scope of the LCA. Final conclusions are drawn and recommendations stated.

[2] Resource extraction and emission of pollutants

2 Goal and scope

2.1 Outline of the study

The food offered during the 41st discussion forum was assessed to present the concept of Swiss ecological time unit to the participants (Jungbluth 2010). Among the beverages, coffee and tea were served. Due to the absence of a dataset on tea, its environmental impact was assumed to be similar to the coffee (Büsser & Jungbluth 2009). However, it had never been checked if the amounts of pesticides use in tea cultivation were similar to the coffee amounts. Besides, the processing of coffee berries is quite different from the processing of fresh tealeaves. Thus, this study aims to provide life cycle inventory data on tea to complete the ESU-database (Jungbluth et al. 2010). This is an internal study made during an internship at ESU-services Ltd..

The questions are the following:

- What are the environmental impacts of the tea cultivation? Are they similar to coffee?
- What are the impacts of tea manufacturing?
- What are the impacts of tea preparation?
- Which packaging has higher environmental impacts?

2.2 Functional unit and reference flow

In this study, black tea has been assessed and more precisely Darjeeling tea which is cultivated in the Darjeeling area in Northern India.

Tea is mainly consumed in tea bag or as loose tea packed in large package and dosed by the final consumer. Tea bags contain in average 1.75g of broken tealeaves while the amount of loose tea depends on the consumer's taste and the type of tea. It has been assumed that in case of loose tea consumption, 1.75g of tea are also used. Thus, the functional unit is the preparation of one cup (250 ml) of tea ready to drink at home in Europe and the reference flow is 1.75g of dry tea leaves.

2.3 System boundaries

The system boundaries and the main life cycle stages are depicted in Fig. 2.1.

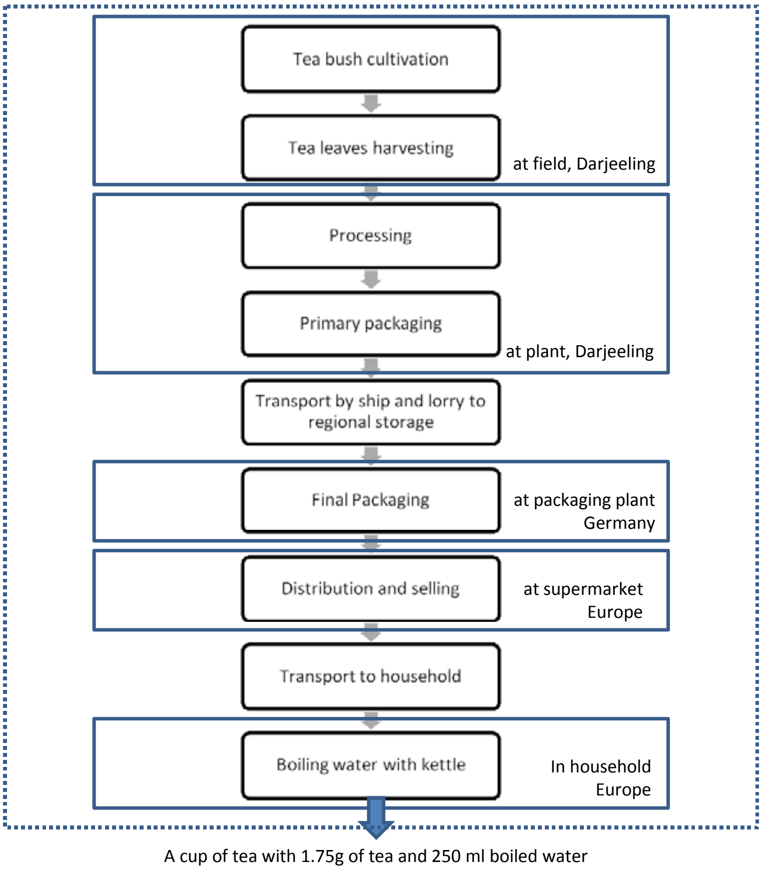

Fig. 2.1 Process chart for the production of tea from tea plant

2.4 Scenarios investigated

The cultivation takes place in India. The agricultural practice is either organic with the use of fertilisers or conventional with the additional use of pesticides. Organic and conventional fresh tea leaves are dried in the same way but in different processing plants to avoid any contacts between the tea leaves. Then, tea in primary packaging is shipped to Europe. The final packaging is either tea bags or multi-walled large package containing loose tea. Then, tea is distributed and sold in European supermarkets. After the consumer's purchase, tea is prepared in household with water boiled in an electrical kettle. Overall, five life cycle scenarios have been assessed:

1) Organic cultivation and packaging in tea bags
2) Organic cultivation and loose tea in multiwalled large package
3) Organic cultivation and loose tea in multiwalled large package without distribution in supermarket. The reason for not including the distribution is to model the life cycle of Teekampagne Darjeeling tea, which is directly sent to the final consumer in private parcel.
4) Conventional cultivation and packaging in tea bags
5) Conventional cultivation and loose tea in multiwalled large package

2.5 Life cycle impact assessment methods

In this study we apply three methods for the life cycle impact assessment (LCIA) namely the ecological scarcity method 2006 (Frischknecht et al. 2009), the global warming potential (GWP or carbon footprint) (Solomon et al. 2007) and the non-renewable cumulative energy demand (Frischknecht et al. 2007).

3 Life Cycle Inventory of Tea

There are three races of tea plant according to the Tea Research Association in Calcutta[3] The first one is *Camellia sinensis (L)*, which is also called the China tea plant. It is a big shrub, 1-2 m tall. The second one is *Camellia assamica* also called the Assam tea plat, which is a small tree, 10-15m tall with a trunk sometimes up to one third of its height. The third one is *Camellia assamica sub specie lasiocalyx* also called the Cambodiensis or Southern form of tea is a small tree, 6-10 m tall. Tea is originally from China but now it can be cultivated all around the world where well-drained fertile acid soils are found.

China and India share 54% of the world production of tea (Tab. 3.1). The consumption inland is high so only one quarter of the production is exported. The third producer Kenya exhibits different trade characteristics. All the tea production is exported. China, Kenya and Sri Lanka earn benefits around 500'000 US-$ while exporting. Surprisingly, India doesn't earn much.

Tab. 3.1 Overview of the top 5 tea producers in 2007 (FAOSTAT, Crops production 2007)

	Production 1000 t	Share	Area harvested 1000 Ha	Crop yield t/Ha	Net export 1000 t	Share	Net export 1000 $
China	1183	30%	1175,7	1,01	292	25%	469
India	949	24%	567,0	1,67	193	20%	5
Kenya	370	9%	110,5	2,48	374	101%	699
Sri Lanka	305	8%	48,2	1,43	190	62%	545
Turkey	206	5%	149,2	2,71	3,3	2%	5,5
World	3903	100%	2847,3	1,37	1702		

The cultivation and harvest of black tea is the same as for green and other fermented tea. The final product is determined by the processing of tealeaves. In this study, the focus is on Darjeeling tea. It is produced in a specific region that is located in northeast of India around Darjeeling city. Its name is protected by a Geographical indication meaning that the product is originating from a region where quality, reputation and other characteristics are attributable to this area. It cannot be replicate anywhere. For these reasons, the life cycle inventory of Darjeeling tea is easier because cultivation, harvest and manufacturing processes are well defined. The Darjeeling area is member of the Tea Research Association (TRA) and useful information is found on its website[3].

The study was carried on during an internship at ESU-services from June to July 2010. Apart from completing the ESU database, the idea was to become familiar with the life cycle assessment methodology. Due to the short time available, it was quite difficult to organize a contact with a tea company in order to gather verified and representative data.

In order to do the life cycle inventory, quantified information was needed on cultivation, processing, packaging. Neither previous LCA studies on tea were found nor scientific papers were found on energy quantification of processing apart from one in Sri Lanka. A paper focusing on biodiversity in tea gardens was helpful for quantifying the types and quantities of pesticides used. The information missing was found on Indian Tea research institutes 'websites, which must be acknowledged for the details provided. Thus, data are mainly unverified and representative for some sites. In most of the cases, the time and geographical correlation are unknown or as broad as North India. The company Teekampagne, based in Potsdam, kindly provided us with some information about production yield, processing yield and description of the Darjeeling production chain.

[3] Tea Research Association. Welcome to Tocklai Experimental Station: TRA, www.tocklai.net, July 6 2010

The full life cycle inventory analysis is mainly based on information found in the internet. Different information sources had to be linked. It is documented in a confidential annex that can be purchased from ESU-services on request (Jungbluth et al. 2010).

4 Life cycle impact assessment

4.1 Production of tea

Tab. 4.1 shows the shares of the different life cycle stages for the five scenarios with regard to the ecological scarcity 2006 method. Because boiling water is not in the responsibility of the production chain (and its high impact as one can see in chapter 4.2.2and 4.2.3 for further details), this process hasn't been included in this first evaluation. We investigate the contribution of cultivation, processing, transport, packaging, distribution in supermarket and transport to household. Most important is the cultivation of tea bushes due to the use of pesticides and fertilisers with an average 70% of the total impacts followed by the processing of the tea leaves, which accounts for about 15% of the total impacts. Obviously, the share of packaging increases when tea bags are used in the life cycle. The transports from the field in India to the distribution centre in Europe are of minor importance, around 2%.

Tab. 4.1 Results of the production of a cup of tea without any preparation with regard to the ecological scarcity 2006 method. All results are scaled to 100%

	organic loose tea	organic tea in bags	organic loose tea, no distribution	conventional loose tea	conventional tea in bags
Cultivation and harvest	71%	59%	75%	83%	74%
Processing	18%	15%	19%	11%	10%
Transport	3%	2%	3%	2%	1%
Packaging	2%	14%	2%	1%	9%
Retail/Distribution and selling	4%	7%		3%	5%
transport groceries to household	2%	2%	1%	1%	2%
Total	100%	100%	100%	100%	100%

4.2 Tea consumption

4.2.1 Ecological scarcity 2006 method

Fig. 4.1 shows the single score eco-points of the preparation of a cup of tea for the five scenarios with regard to the ecological scarcity 2006 method. In comparison to Tab. 4.1, Fig. 4.1 shows the impacts in terms of emissions into different compartments and includes the boiling of water. In case of organic tea, most important are the emissions into air caused by the electricity and heat used during processing. The share is similar in case of conventional tea because the processing stage is the same. A higher share for organic tea is explained by the use of compost in the organic cultivation. However, the main difference between organic and conventional tea is the share of emissions into top soil due to the use of pesticides in conventional cultivation. In total, a cup of conventional tea has around 85 eco-points whereas a cup of organic tea has around 64 eco-points.

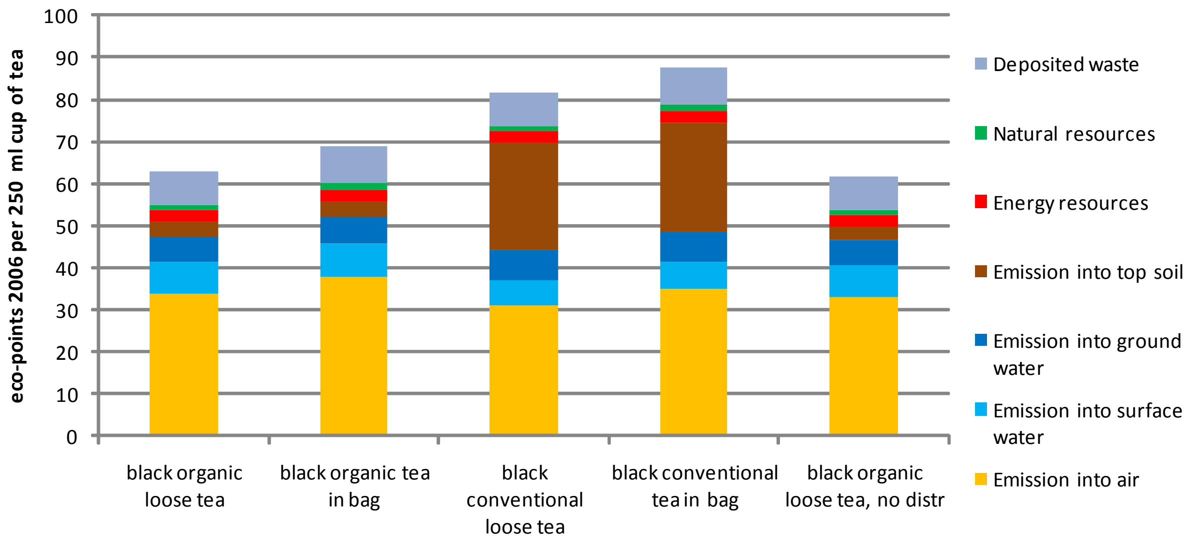

Fig. 4.1 Results of a cup of tea with regard to the ecological scarcity 2006 method (eco-points per 250ml of tea).

4.2.2 Carbon footprint of tea

A carbon footprint study on tea was presented by Nigel Melican during the 2009 world tea expo in Las Vegas. Thus, the GWP of the five scenarios is calculated in this study and compared with the available data provided on internet.[4] The results are shown in Tab.4.2. The highest figures in the "very high" scenario result from the use of mineral water for the preparation of tea instead of tap water and burning coal for drying tea.

As can been seen on Tab.4.2, the main CO_2 intensive processes are the preparation of a cup of tea at household and the processing. Indeed, the processing of the fresh tea leaves amounts to 13-15% of the total carbon footprint and the boiling of water in an electric kettle at home causes 64-73% of the total carbon footprint. The reason is that both processes require electricity in large amount. These two processes would be first targets for CO_2 reduction. In contrast transports of tea from tropical countries to Europe do play a minor role in the assessment.

Another issue is the comparison between organic and conventional cultivation. The growth of organic tea amounts to 10-11 % of the total carbon footprint while it is only 6-7% for conventional cultivation. The reason is the use of large quantities of compost, which emits fossil methane in the air and contributes to 9% of the total GWP. On the other hand, 5.5% of the total GWP is due to use of N-fertiliser in the conventional cultivation.

Overall, if the total carbon footprint of the different Darjeeling tea are compared with the three categories defined, they are considered to have a "typical" carbon footprint with an average of about 48 g CO_2-eq per cup.

[4] Retrieved June 2010 from http://www.passeportsante.net/fr/Actualites/Nouvelles/Fiche.aspx?doc=bilan-carbone-ecolo-votre-tasse-de-the-200909259

Tab.4.2 Comparison between results of a cup of tea with regard to the global warming potential with results of a carbon footprint study on tea in 2009 [5]

Carbon footprint	Very high	Typical	Very low (good)	organic, loose	organic, tea bag	conventional, loose	conventional, tea bag	organic, loose, no distr
	g CO2/cup	g CO2/cup	g CO2/cup	g CO2/cup	g CO2/cup	g CO2/cup	g CO2/cup	g CO2/cup
Cultivation and harvest	5,6	2	1,4	5,1	5,1	3,0	3,0	5,1
Processing	10,2	3,3	0,8	6,6	6,6	6,6	6,6	6,6
Transport	1,9	0,8	0,6	0,9	1,2	0,9	1,2	0,8
Packaging	10	2,3	1,3	0,4	3,6	0,4	3,6	0,4
Retail/Distribution and selling	0,3	0,3	0,3	1,1	2,2	1,1	2,2	0,0
Preparation of cup	142	31	15	33,0	33,0	33,0	33,0	33,0
Total	**170**	**39,7**	**19,4**	**46,9**	**51,6**	**44,9**	**49,5**	**45,9**
source : Nigel Melican (2009)				source: SIMAPRO CML GWP 2007; July 20 2010				

Fig. 4.2 depicts the same results even though the category cultivation includes the cultivation and the processing. It is relevant to notice the negligible share of packaging and distribution compared to cultivation and preparation. The fifth case looks similar but for the packaging and distribution shares, which are bigger when tea bags are considered rather than loose tea.

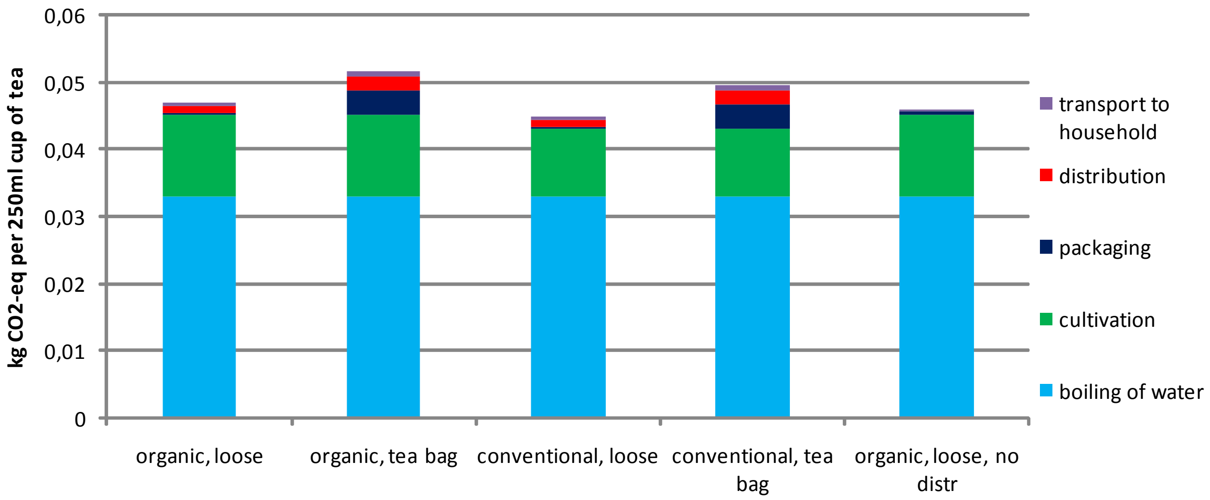

Fig. 4.2 Results of a cup of tea with regard to the global warming potential.

4.2.3 Non-renewable cumulative energy demand (CED)

Results are similar when a cup of tea is assessed with the non-renewable cumulative energy demand as can be seen on Fig. 4.3. The share of boiling water is even higher while it is difficult to differentiate organic from conventional cultivation due to the fact that the processing is the same for both and it is the main contributor to the energy demand.

[5] Nigel Melican Carbon Footprint on Tea (2009). Retrieved from http://www.passeportsante.net/fr/Actualites/Nouvelles/Fiche.aspx?doc=bilan-carbone-ecolo-votre-tasse-de-the-2009092590

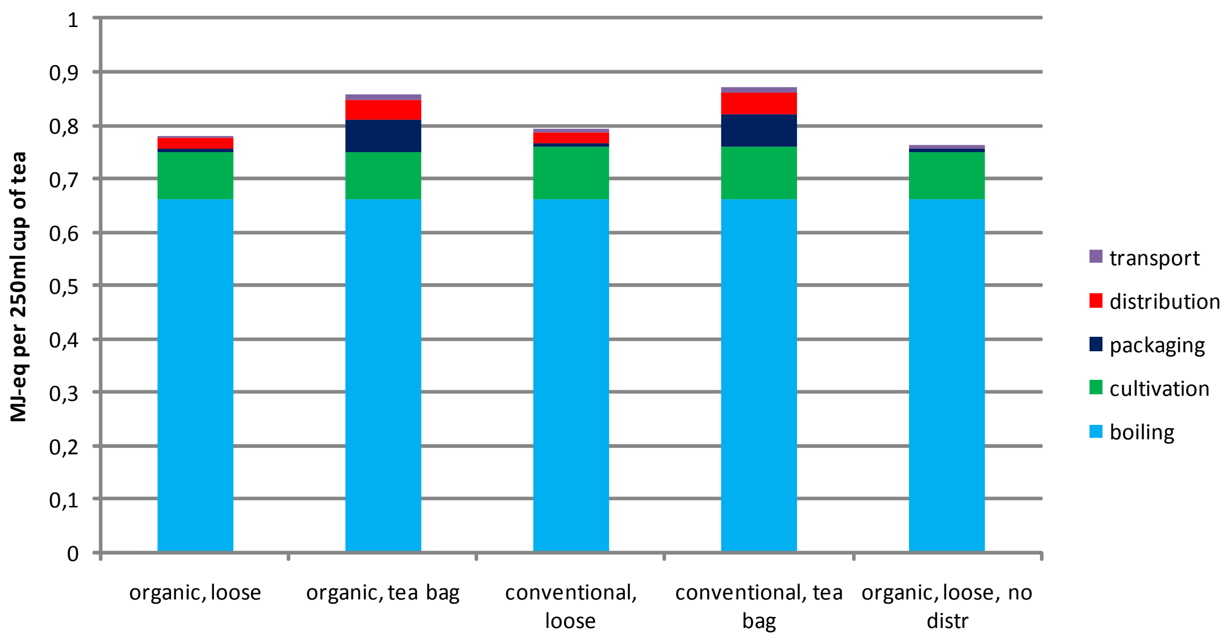

Fig. 4.3 Results of a cup of teas with regard to non-renewable cumulative energy demand.

4.3 Comparison between a cup of tea and a cup of coffee

Similarly to tea, coffee is also consumed in two main ways. Single serving sticks contain 2g of coffee while ground coffee is usually brewed with a coffee machine and 7g coffee are used per cup. In both cases, the amount of water is 125ml, half the amount to prepare a cup of tea (Büsser & Jungbluth 2009).

4.3.1 Global warming potential 2007

In Fig. 4.4, tea and coffee are compared with regard to GWP. The GWP of a cup of tea is around 48 g CO2-eq whereas it reaches 114 g CO2-eq per cup of coffee. This is explained by the difference in the cultivation yields and differences in the processing of the coffee berries and the fresh tea leaves. While 1kg of ground coffee require 6.5 kg of coffee berries, 1kg of loose tea needs only 4 kg of fresh tea-leaves. Also the boiling of water is less efficient in the automatic coffee machine compared to the kettle used for tea.

The results in Fig. 4.5 are similar to the ones in Tab.4.2. Indeed, the main contributors for the carbon footprint are the cultivation and the preparation. In this case, the cultivation of tea includes the cultivation and the processing in India and the transport to the regional storage in Germany. Thus, the share is higher than the one mentioned in part 4.2.2. In the case of coffee, it includes cultivation of coffee berries, drying, roasting and grinding. This is the reason why its share is bigger than for tea.

The preparation of a cup of a tea is the same for all cases; 250 ml of water is boiled with an electric kettle. The preparation of a cup of coffee is also the same for ground and instant coffee with a coffee machine as it can be seen on Fig. 4.4. However, the share of the preparation differs for each case as shown on Fig. 4.5.

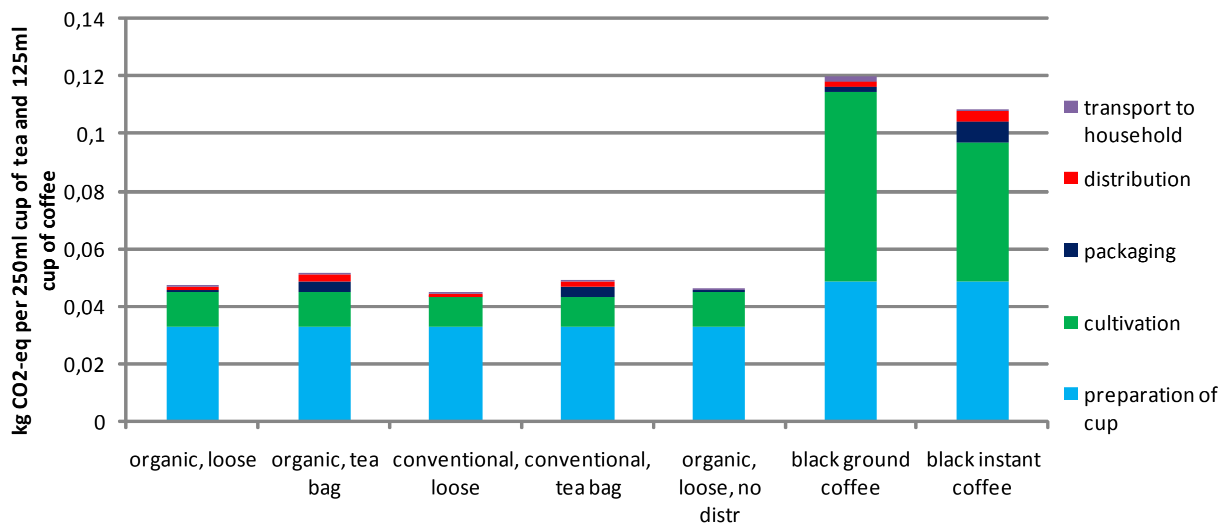

Fig. 4.4 Results of the comparison of a cup of black tea and a cup of black coffee with regard to the global warming potential.

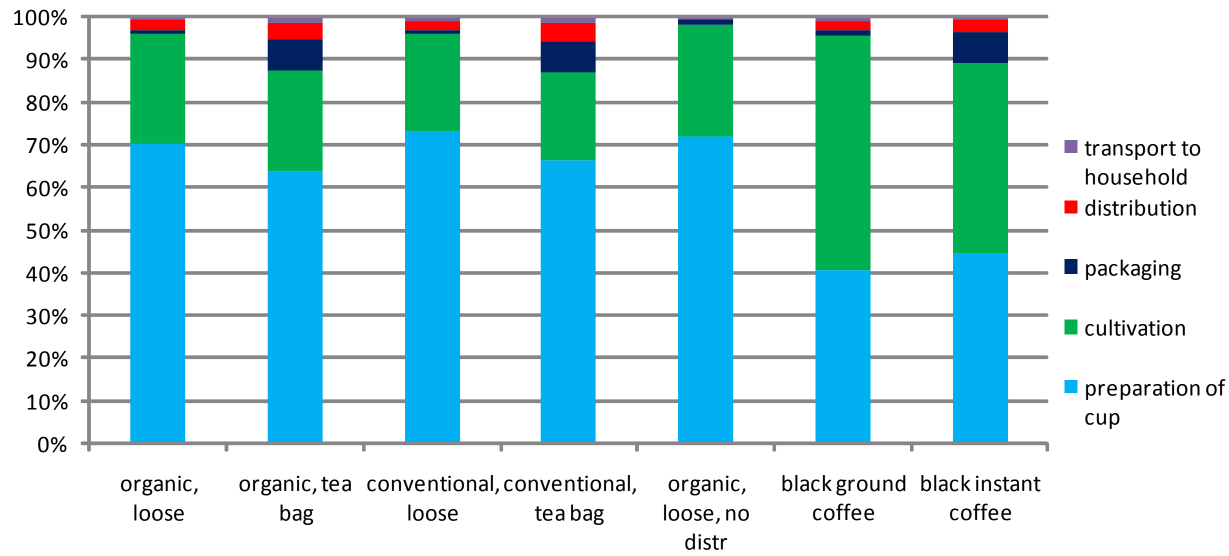

Fig. 4.5 Results of the comparison of a cup of tea and a cup of coffee with regard to the global warming potential. Results are scaled to 100%. Results are scaled to 100%.

4.3.2 Non-renewable cumulative energy demand (CED)

In Fig. 4.6, tea and coffee are compared with regard to non-renewable energy demand and it can be seen that the CED of a cup of tea is half the one for a cup of coffee. The difference in boiling, even though the amount of water is lower for a cup of coffee, is due to the higher energy consumption of a coffee machine compared to an electric kettle.

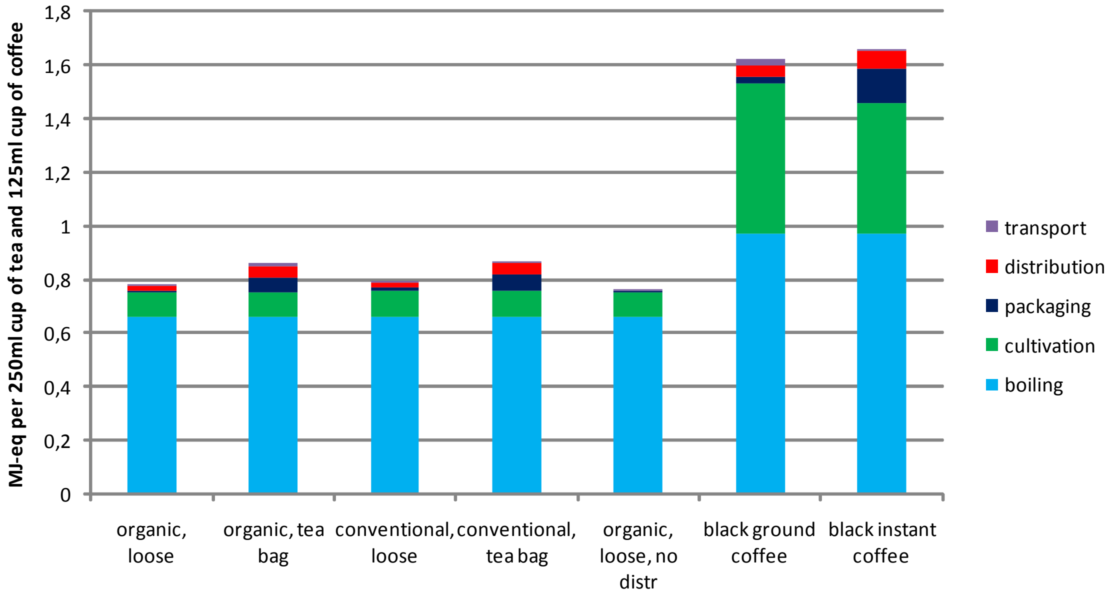

Fig. 4.6 **Results of the comparison between a cup of coffee and a cup of tea with regard to the non-renewable cumulative energy demand.**

However, Fig. 4.6 shows that the share of cultivation and processing of coffee berries is higher than the ones for tea cultivation and processing for the same reasons explained in the GWP analysis (part 4.3.1).

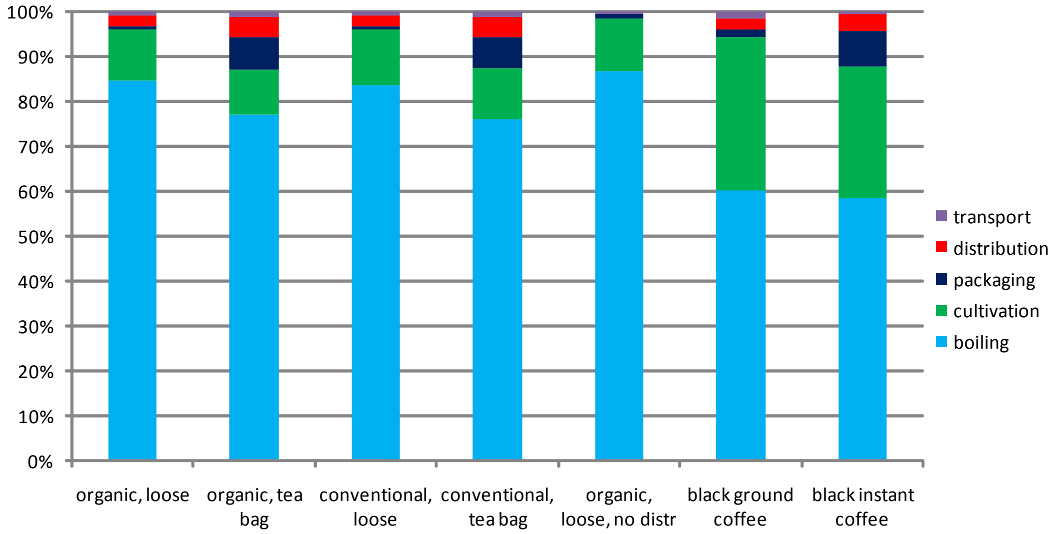

Fig. 4.7 **Results of the comparison between a cup of tea and a cup of coffee with regard to the non-renewable cumulative energy demand. Results are scaled to 100%.**

4.3.3 Ecological scarcity 2006 method

In Fig. 4.8, tea and coffee are compared with regard to the ecological scarcity 2006 method. Fig. 4.8 shows that the absolute single score of a cup of tea is around 72 eco-points, which is 5-7 times lower than the single score of a cup of coffee around 370 eco-points. This is even more surprising considering that a cup of coffee is only half the amount of liquid. The cultivation of coffee berries accounts for 83% of the total single score while it is only 47% for conventional loose tea

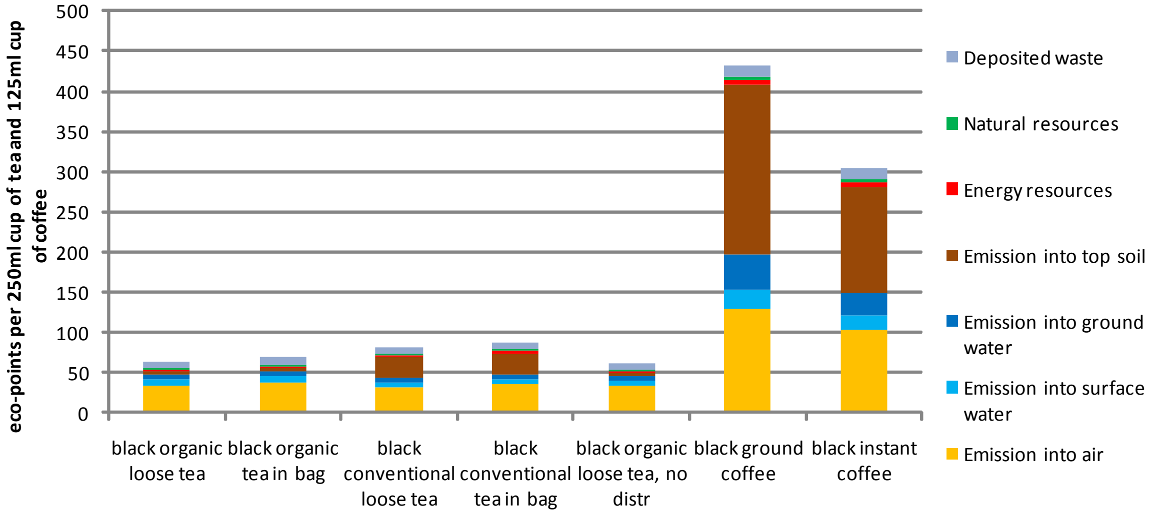

Fig. 4.8 Results of the comparison between a cup of tea and a cup of coffee with regard to the ecological scarcity 2006 method.

Fig. 4.9 shows the relative values to facilitate the comparison of the share of the different emissions categories. The two relevant categories are emissions into air and emissions into top soil. Due to the absence of pesticides use in organic cultivation, the share of emissions, around 5%, into top soil is negligible for organic tea while it is 30% for conventional tea. On the other hand, the share of emissions into air for organic tea, around 55%, is higher due to the use of compost. 21% of emissions to air are cause by the cultivation of organic loose tea while it is only 13% for conventional loose tea.

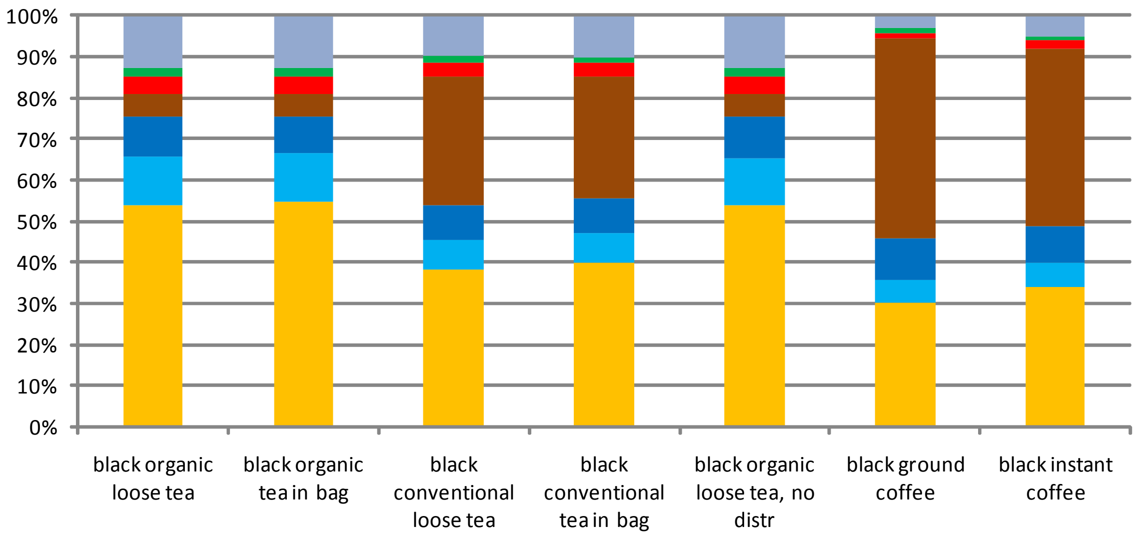

Fig. 4.9 Results of the comparison between a cup of tea and a cup of coffee with regard to the ecological scarcity 2006 method. Results are scaled to 100%

4.4 Recommendations

The first obvious recommendation deals with the preparation of a cup of tea at home. As it was shown with the different assessment methods, around 70% of the total impacts are caused by the electricity consumption for boiling the water. Thus it is of key importance that the consumer adopts an economical behaviour and reduces the excess amount of boiled water and invest in an energy-efficient kettle.

The second issue refers to the processing of the tea leaves. Actually, the study focuses on Darjeeling tea, which is still processed in a conventional way to preserve the high-quality the dried leaves. Thus the technology used is old and energy-consuming compared to new machines available and use for other black tea. For instance, Darjeeling tea leaves are dried by being carried on a conveyor through which pressured hot air is blown. In an alternative technology called fluidised bed dryer (FDB), hot air is blown directly into the drier and the process of fluidisation moves the leaves. The throughput is higher and the fuel consumption per kg of tea is half the amount used in a conventional dryer.

However, when tea is compared to coffee, its environmental impacts are lower in terms of eco-points. It was found that because ground coffee requires more processing steps and a higher quantity of coffee berries from the field, the overall impacts are higher. In conclusion, the assumption of using the coffee life cycle for tea for the environmental product information wasn't appropriate and led to a slight overestimation of the environmental impacts.

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