Comparing two LCA approaches for the transport of milk from farms to processing plants in Switzerland

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ABSTRACT

The environmental impact of transporting milk from farms to processing plants depends mainly on the distance and the operating parameters of the vehicles (Foster et al. 2006). The aim of this study is to compare different LCA approaches for the quantification of the environmental impact of a milk collection round trip in Switzerland. We considered two approaches: The simplified approach, where the average distance between farms and processing plant and standard emission factors for the relevant truck type were used and a detailed approach, where the effectively driven round trip was considered. For all analyzed impact categories, the simplified approach results in a smaller impact compared to the detailed approach. The selection of a modeling approach for transports depends on the way how a transport is being organized but also on the importance of transport's impact of the whole life cycle.

Keywords: LCA, transport, milk, collection round trip

1. Introduction

In Europe, food and drink products are responsible for 20-30 % of the environmental impacts of private consumption (Tukker et al., 2006). Although transport occurs between each step of supply chains, it often has an insignificant influence on the total environmental impact of agricultural products, especially of animal products such as milk. Bystricky et al. (2014) conclude after analyzing five different agricultural products (plant and animal products) from different provenance that the part of the total environmental impact of transportation is larger for products with small environmental impact per unit such as potatoes. Foster et al. (2006) give a value of 0.0068 kg CO_2 for direct emissions per kilogram milk transported, which corresponds to 0.66 % of the total greenhouse gas (GHG) emissions from milk at farm gate. Due to this negligible role of transports on the total environmental impact of food products, transports are often modelled with average parameters in LCA. For example, Pattara et al. (2012) calculated the environmental impact of wine transportation using averaged values. Further examples can be found in the publications of González-Garcia et al. (2013), Heller et al. 2008 and Browne et al. (2005). In all those studies, transports were considered based on average transport distances between point of collection and point of delivery and average life cycle inventories. Average life cycle inventories for transport, such as those in ecoinvent, are based on average load and empty trip factors. In the case of ecoinvent, the load factor including empty trips for lorry transports used is 50 % (Spielmann et al. 2007). However, the variability between single transport services is very high, thus such average factors might not be representative. In the case of line haul transports for example, load factors can be as high as 100 % with no empty trips. In this situation a fully loaded truck will only drive the distance once to transport its products, in a situation where the truck would have been only half loaded, it would have to drive the distance twice to transport the same amount. Considering a higher fuel consumption of fully loaded trucks of approx. 21 %, which is the difference in fuel consumption of the two processes “operation, lorry 20-28t, fleet average” and “operation, lorry 20-28t, full, fleet average” (both from Spielmann et al. 2007), total fuel consumption for a transport in a fully loaded truck would still be about 40 % lower compared to a transport in a half loaded truck. Thus, using average emission factors for line haul transports would lead to an overestimation of the environmental impact. On the other hand, for transports with lower load and higher empty trip factors, averaged data would lead to an underestimation. This might be the case for transports organized as collection or delivery round trips, which are distinguished from common transport services by the European standard EN16258:2012 – “Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)”.

An agricultural product that is typically transported in collection round trips is milk. The goal of this study is to find out whether there is a significant difference between a detailed LCA of the collection round trip and a simplified approach using average transport inventories and average direct distances from the points of collection to the point of delivery.

2. Methods

Two different LCA approaches for the quantification of the environmental impact of a milk collection round trip in Switzerland are compared. One approach is a simplified approach, where standard life cycle inventories for the relevant truck type and average distances between farms and dairy processing plants were used. The second approach is more detailed, as the effectively driven distance and specific fuel consumption are considered following the recommendations for collection round trips of the European standard EN16258:2012 (CEN, 2012). The calculations are performed on one exemplary milk collection round trip in the canton of Thurgau in Switzerland. A carrier specialized in milk transports provided the primary data, background data were taken from the ecoinvent V2.2 database (ecoinvent, 2010).

2.1. Functional unit and system boundaries

The functional unit is the delivery of one kilogram milk. The system boundaries comprise all transport related life cycle phases such as direct emissions, fuel production, vehicle manufacturing, maintenance and disposal, and road infrastructure. The milk production, processing, trade and consumption are excluded in this study (Figure 1). The time boundary is the year 2013.

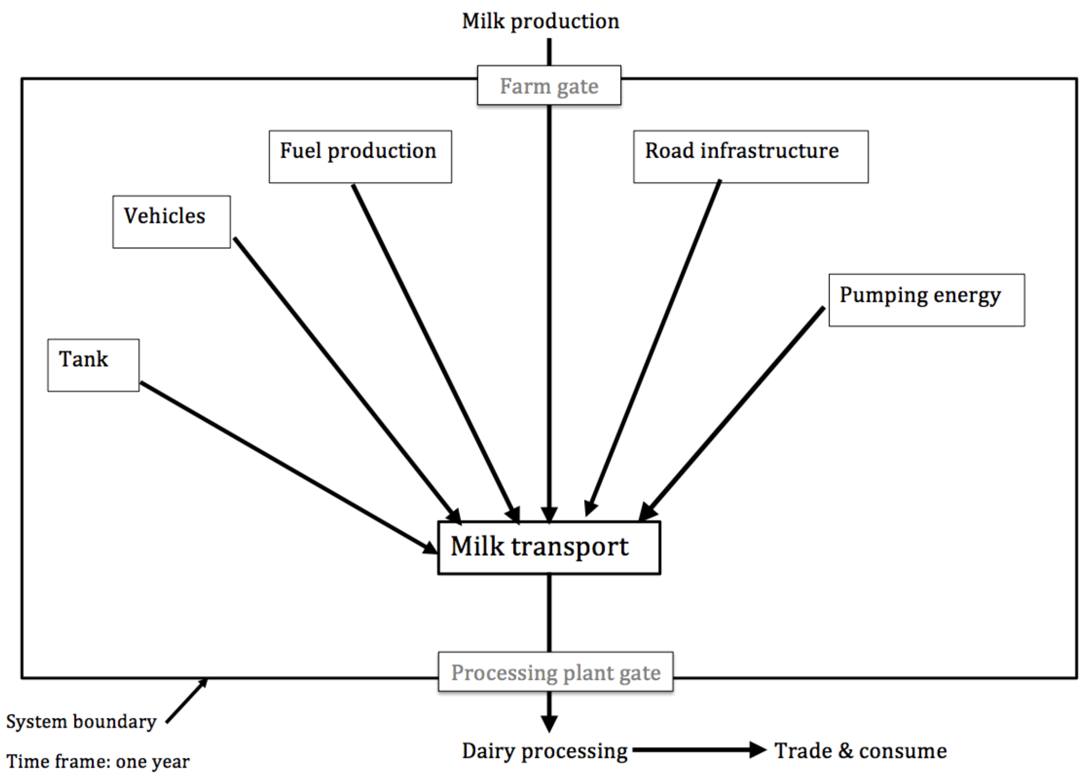

Figure 1. Initial system boundaries definition.

2.2. Impact categories

The European standard EN16258:2012 (CEN 2012) is a guideline for the calculation of GHG emissions and energy consumption of transport services. Therefore we decided to use those two impact categories for our study, assessing the global warming potential (GWP) as well as the non-renewable energy demand (NRED) (fossil and nuclear energy). These two categories are thought to be the most important categories for environmental impact quantification of transport services since they are directly influenced by the fuel combustion process and production, respectively. In order to complete the picture, we decided to integrate the impact category human toxicity (HT), as it was the impact category contributing the third-most to the aggregated environmental impact when using the impact assessment method ReCiPe 2008 (H) with normalization for Europe. Table 1 shows the considered impact categories and the applied methods.

Table 1. Impact categories and corresponding impacts assessment method and impact factor's unit.

Impact category	Impacts assessment method	Impact factor's unit
Non-renewable energy demand (NRED)	According to ecoinvent; Frischknecht et al. 1998	MJ eq
Global warming potential (GWP)	IPCC 2007, 100a	kg CO_2e
Human toxicity (HT)	USES-LCA 2.0	kg 1,4-DB eq

2.3. Data collection

2.3.1. Selection of the round trip

A milk collection round trip in the canton of Thurgau in the northeast of Switzerland was selected. As only one round trip is analyzed, and the variability of milk collection round trips are probably high, results for this route are not expected to be representative. However, it will allow us to highlight some trends in the environmental impact calculations of transport.

The analyzed round trip is done by truck and runs every second day of the year. It collects milk from 21 farms and is approximately 80 km long. The driven distance includes empty runs. At the farms, a pump powered by the truck's engine pumps the milk into the truck's tank which means that the truck engine never stops running during the whole collection round trip (oral communication).

2.3.2. Data sources

The carrier provided primary data for the round trip, truck type and fuel consumption. The tank vendor provided data for the tank. All data was collected for the calendar year 2013. The provided fuel consumption data was not measured, but estimated by the carrier. They were 30 % higher compared to the average fuel consumption of the same truck type from the corresponding ecoinvent process, which can be explained by the extra diesel consumption for the pumps, and therefore we considered them as plausible. Data for road and vehicle infrastructure were based on ecoinvent v2.2 and literature. Demand factors were calculated following the same procedure as in ecoinvent (Spielmann and Scholz, 2005).

2.3.2. The two modelling approaches

The simplified approach is calculated with the ecoinvent transport process "transport, lorry 20-28t, fleet average", a truck type comparable to the one used for the studied transport service. This process includes all the above mentioned transport related life cycle phases for transports with average load factors. The functional unit of this process is a ton kilometer. The ton kilometers needed for the delivery of one kilogram milk are calculated taking the average of the distances from each farm on the collection round trip to the processing plant.

The detailed approach is based on the same ecoinvent process, with some adaptations to reflect the real situation in a better way. First, instead of using ton kilometers, the process "transport, lorry 20-28t, fleet average" is converted from ton kilometers to vehicle kilometers, which allowed us to consider the whole collection round trip, starting and ending at the parking place of the truck according to the definition of vehicle operation systems (VOS) in the European standard EN16258:2012 (CEN 2012). The truck manufacturing, maintenance and disposal is changed according to the effective vehicle weight and complemented with the tank. For the operation of the truck, fuel consumption on the round trip is adapted, so that it includes the required energy for the pumping of the milk into the tank at the farms and collecting sites. Afterwards the total emissions of this trip are divided by the amount of milk delivered per trip, resulting in emissions for the delivery of one kilogram milk.

3. Results

Transport life cycle was divided into eleven phases for the detailed approach: 1) truck manufacturing; 2) truck maintenance; 3) road operation, maintenance; 4) road construction; 5) truck tank; 6) trailer tank; 7) truck operation; 8) truck disposal; 9) road disposal; 10) truck tank disposal; 11) trailer tank disposal. The results are shown in Figure 2.

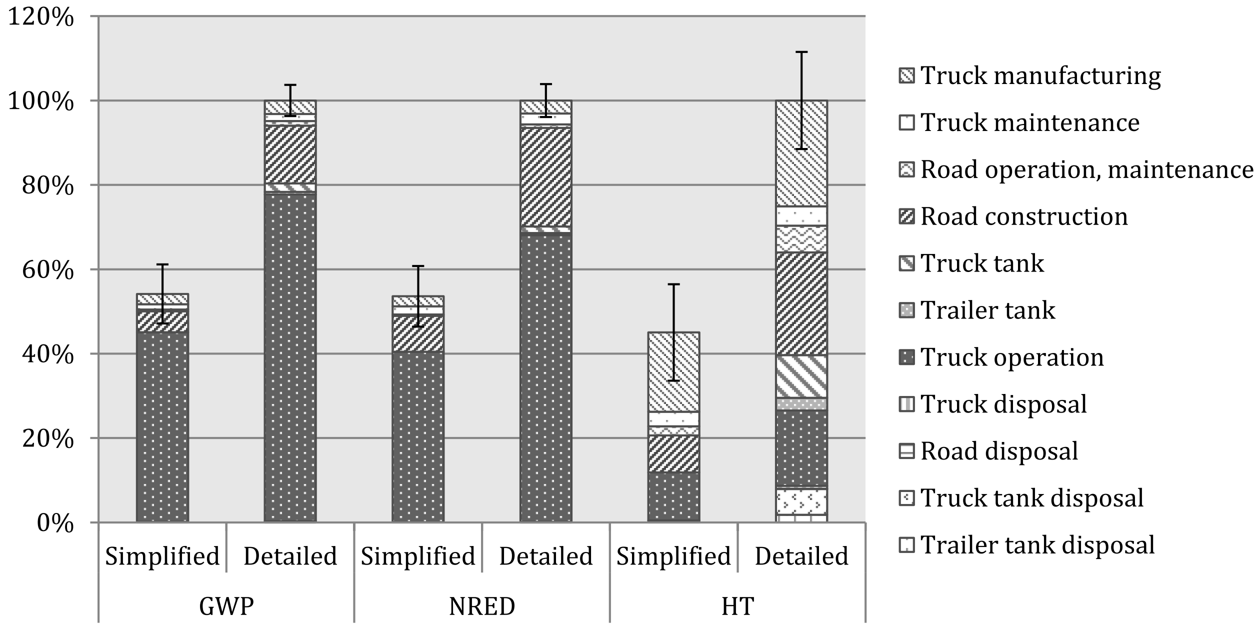

Figure 2. Comparison of the simplified and detailed approaches for the impact categories GWP, NRED and HT.

For the categories global warming potential (GWP) and non-renewable energy demand (NRED), the impacts of the simplified approach are approx. 50 % lower than those of the detailed approach and for the category human toxicity (HT) approx. 55 % lower.

In our detailed approach, the total GWP is 0.00517 kg CO_2e / kg delivered milk. The truck operation contributes 77 %, due to the direct emissions of the fuel combustion and from the fuel production linked emissions. The rest of the CO_2e emissions are caused mainly by the road construction which contributes 14 % to the GWP.

Total NRED in the detailed approach is 0.08170 MJ eq / kg delivered milk. Like for GWP, the truck operation contributes the most with 68 % of total NRED. This apparent correlation between the category GWP and NRED arises from the fuel consumption. NRED impact is determined by the fossil energy use. The impact on GWP is determined mainly by the combustion of the fuel for transportation.

For HT, the transport cause 0.00068 kg 1,4-DB eq / kg delivered milk. This impact is, compared to GWP and NRED, caused by other sources: 25 % of the total impact is caused by truck manufacturing and further 24 % by road construction. During the manufacturing of the truck reinforcing steel dust is generated and needs to be disposed. The impact on HT of the road construction arises from the bitumen which is produced with crude oil. During the crude oil extraction, formation water needs to be drained. Further, two other phases influence this impact category: truck tank (10 %) and truck operation (18 %). Same as for the road construction, the impact of the truck operation arises from the fuel production which requires crude oil extraction. Moreover, the impact on HT of the truck tank is due mainly to the chrome steel production which requires the burning of bituminous coal as energy source. This source of energy emits a lot of particles to the air (mining and burning) and, in addition, ashes emerge which need to be disposed in a residue landfill.

4. Discussion

4.1. Most important sources for environmental impacts of transports

Considering the main contributors to transport emissions, the results of this study are in line with the results of other LCA studies on transportation. The main cause for environmental impacts of transport arises from the fuel production and combustion for the impact categories GWP and NRED. These results correspond to the findings of Spielmann and Scholz (2005), who affirm that the operation component has the largest environmental impact of transport services. Eriksson et al. (1996) also determined the fuel combustion as having the largest impact followed by the fuel production.

For HT, Spielmann and Scholz (2005) found that the particulate matter 2.5 (PM2.5) and non-methane hydrocarbons (NMHC) emissions are influenced mainly by the transport infrastructure. PM2.5 can arise to some extent from the bituminous coal extraction and burning (WHO 1986). In our studied transport, the main causes for HT are also related to transport infrastructure, such as roads and vehicles.

4.2. Putting it into the larger context – the impact of transport in relation to the whole life cycle of products

According to the results of Browne et al. (2005), who reviewed different studies concerning supply chain LCA, the proportion of energy accounted for by commercial freight transport varies in many cases from 2 to 9 %. In a study on the carbon footprint of milk in Switzerland, Alig et al. (2011) calculate an impact of 5 MJ eq per kilogram milk at farm gate. The value for the category NRED obtained in the present work for milk collection transportation represents 1.6 % of this value. For the whole life cycle of milk, the importance of the energy consumption of milk collection will be even lower, proving that the transport life cycle phase is almost not relevant for animal products. This was also observed by Bystricky et al. (2014).

For GWP, Alig et al. (2011) found emissions of 1.3 to 1.4 kg CO_2e per kilogram milk at farm gate, thus our 0.00517 kg CO_2e per kilogram delivered milk only result in 0.4 % of this impact, which is a very small share. Our transport related values for GWP per kg of delivered milk are slightly lower than found in other studies. Foster et al. (2006) give a value of 0.0068 kg CO_2 for direct emissions per kilogram milk transported. Since the procedure and assumptions for the modeling of transportation are not documented in the study of Foster et al. (2006), it is difficult to assess the differences in results. One explanation could be that the study of Foster et al. (2006) was conducted in Great Britain and that the transport infrastructure and distances differ there from the ones in Switzerland. In our analyzed collection tour, all farms situated within a small perimeter from the processing plant. Another difference could arise from the used transport inventories and emission factors.

Like other studies already pointed out (Eide 2002; Flysjö et al. 2011; Foster et al. 2006; IDF 2009), the transportation impact on GWP and on NRED in the milk production life cycle is very low. The farming phase is much more important with about 75 to 95 % of the total environmental impact of milk production (Berlin 2002; Flysjö et al. 2011; Foster et al. 2006; IDF 2009).

4.3. Why does transport still matter?

Most literature studies use average direct distances for the modeling of transport in their calculations. For example, Pattara et al. (2012) calculated the environmental impact of wine transportation based on “the number of bottles delivered, average distance travelled from the firm to the final market, type of vehicle used and its loading capacity”. Further examples are to be found in the publications of González-Garcia et al. (2013), Heller et al. (2008) and Browne et al. (2005) as average transport distances, average datasets and distance between the point of collection and delivery are considered respectively. However, if transports are organized as collection round trips, using average direct distances from the collecting points to delivery point and average emission factors might lead to an underestimation of transport’s impact. If such a transport is modelled with the effective driven distance, the environmental impacts on the categories GWP, NRED and HT are significantly higher, in our case by a factor of two. Even if in the case of milk transports are still rather insignificant, for products, where transports do matter, such as some plant products and products that are transported over long distances, it might be worth to have a closer look at transport processes. Average transport processes are what they are – just average. Real transport impacts could be both, much higher or lower.

5. Conclusion

In the supply chain of agricultural goods, transportation occurs many times and in different ways. In the present study, transportation of milk from farm to processing plant has been studied on a typical collection round trip in Switzerland. It could be shown that there is a significant difference in the results on transportation environmental impact between a simplified approach based on average distances and standard emission factors and a detailed approach based on the effective driven distance and specific emission factors. In all three analyzed impact categories GWP, NRED and HT, the simplified approach resulted in approximation half as much impact compared to the detailed approach. These differences arise mainly from the fact that the effectively driven distance of round trips are higher, leading to more use of road infrastructure and higher fuel quantity. At the moment, most LCA studies on agricultural goods including transportation in their scope do mostly calculate transportation with data based on average direct distances from collection to delivery points and use standard emission factors. Depending on how those transports are organized, this might lead to an under- or overestimation of transport's impact, as effectively driven distances or vehicle load factors might differ from those of average transports. In our example of milk transport, the impact of transport compared to the one of milk production itself was rather small, and even a doubling of transport's impact did not make it a major contributor to the impact of the whole milk life cycle. However, in cases where goods are transported over longer distances or for plant products that often have a lower environmental impact than animal products, we recommend to have a closer look at how transportation is calculated.

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