ANALYSING ENERGY USE IN SUPPLY CHAINS: THE CASE OF FRUITS AND VEGETABLES AND FURNITURE

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Abstract
An increasing number of producers, retailers and third-party logistics providers are interested in carrying out energy assessments of their product supply chain. This is due to sensitivity about climate change and carbon emissions, but also to high energy prices. This paper presents an analytical approach developed to measure energy use in logistics activities in product supply chains. The approach (based on the Life Cycle Approach) quantifies energy use in transport and logistics activities at all stages of a product's supply chain. The work has demonstrated that such an assessment approach based on the supply chain is useful in comparing the energy use implications of different strategies. This supply chain approach can be used to consider options such as sourcing and distribution centre locations, transport modes, road freight vehicle types and weights, vehicle load factors, empty running, transport distance and the balance between consumer shopping trips and delivery to the home.

Keywords: Supply chain, freight transport, energy use, efficiency, carbon footprint.

Introduction

Producers, retailers and third-party logistics providers are increasingly interested in carrying out energy assessments of the type presented in this paper (LDF, 2008). This is due to sensitivity about climate change and carbon emissions as well as rising energy costs. Some companies are beginning to adopt such approaches as part of their Corporate Social Responsibility (CSR) agenda. The paper illustrates that an assessment approach based on the supply chain is useful in comparing the energy use implications of different strategies that can be followed by companies. The research project on which the paper is based is being carried out by the University of Westminster and INRETS for ADEME (the French Environment and Energy Management Agency). The final objective of the supply chain approach presented here is to contribute to the discussion on carbon footprint of a product by comparing different supply chains, measuring its energy content in a standardised way, quantifying the transport specific energy consumption steps in the supply chain and identifying potential strategic options where logistics choices can be made that lead to reduced energy use.

The case study approach presented here highlights the need for good quality data from the various operations carried out within the supply chains, including factors such as distance travelled, weight moved, vehicle utilisation, storage, handling and consumer behaviour. Therefore, the supply chain approach is potentially very complicated and time-consuming for the researcher. The complexity and the time required to complete the study of a supply chain is strongly influenced by decisions about the emissions to be counted and where the system boundaries are to be drawn: In some cases of Life Cycle Analysis (Browne et al., 2005), or French carbon balance (Ademe, 2007), the complete chain of all suppliers of a company have been assessed. The need to be efficient has lead to the choice of a new survey method, looking only at the fossil fuel energy used from the producer to the consumer, focussing on freight transport movements more than on other specific steps of the chain like agricultural production or recycling economy (Rizet and Keita, 2005,).

Method: Standardise transport and energy consumption values through conversion factors

A central objective has been to obtain a complete figure of the energy content of a "typical" supply chain by focussing on specific products. The research project noted above, focuses on a fresh food product and an item of furniture. The intention of choosing contrasting product types was to investigate the relative difficulties in data collection and analysis and to identify whether the supply chain decisions that can lead to reduced energy consumption may be common across different product categories. Applying this research method should lead to efficient data collection that is relatively simple and fast for the company involved. In line with these principles, the companies surveyed were market leaders in the product category chosen and the case study focuses on products that are sold in high volumes and are generally available all the year round (although the sourcing may change with fresh produce to accommodate seasonality issues).

Different types of transport energy used in the supply chains have been included: diesel for goods vehicles, bunker fuel oil and marine diesel oil for ships. Fuel, gas and electricity data have been collected for storehouses, production plants, distribution centres and shops. At all stages, data for tonnage of the products grown, manufactured, transported, stored or distributed was collected together with the energy use data, for one year.

All energy consumption have been converted into ‘grammes of oil equivalent’ (goe) using coefficients defined in Defra (2007). Grammes of oil equivalent is a unit for measuring energy, and is the amount of energy that would be produced by burning one gramme of crude oil. Conversion into grammes of oil equivalent allows comparison of energy use between different energy sources. The calculation involves:

$$E_{ep} = \frac{(L \times 907) + (E_e \times 121) + (E_g \times 86) + (E_f \times 907)}{M}$$

with:
Eep = Energy efficiency per product unit, in goe per kg
L = Annual fuel use (diesel) of all vehicles in litres (907 is the conversion factor, see Table 1, line 1)
Ee = Annual electricity energy use in kWh
Eg = Annual use of natural gas energy for heating or mobility in kWh
Ef = Annual fuel use for heating in litres
M = Annual volume of products sold in kg

We use for UK in general for growers, production plants, storage places and shops (Table 1). Applying the same principles and factors (Table 1) to a road freight transport leg between two UK sites is fairly simple. The companies provide data on fuel use (mpg), distance, load, truck type and empty runs. The rest of the data is calculated using:

$$E_{ep} = \frac{(L \times (D \div 100) \times E \times 907)}{M}$$

with:
Eep = Energy efficiency per product unit, in goe per kg
L = Mean fuel use (diesel) of all vehicles of the fleet (converted in litres/100km, Table 3)
D = Distance covered between origin and destination of the supply chain leg
E = Empty running factor (1 = no empty running; 2 = one empty return trip etc)
M = Annual volume of products sold in kg
907 = Energy conversion factor for diesel fuel (Table 1, line 1)

For sea transport, the principle is the same as for road. In addition, other specific indicators are needed: route and ports of shipping line, nautical miles between all ports, vessel load factor in TEU or % of nominal carrying capacity, mean container load factor in tonnes on this route, motor fuel use per day at sea and day at ports, number of days at sea and in ports.

	Energy conversion factors							Emission factors
Fuels	litre	m^3	= kg	= kWh	GJ/tonne	= GJ	= goe	= $kgCO_2eq$
Diesel	1		0.8312	10.551	45.7	0.0380	907	2.630
Petrol	1		0.7385	9.477	46.2	0.0341	815	2.300
Heavy fuel oil	1		0.9737	11.765	43.5	0.0424	1,012	3.177
Natural Gas		1		11		0.0396	946	2.090
Sources Nr			(1)	(2)	(1)	(3)	(3)	(2)

Table 1: UK conversion factors for energy, fuel consumption and CO_2 emissions

Sources: (1) DTI 2007 ; (2) Defra 2005; (3) DTI 2007 and Defra 2005
Notes: **goe** - Gram oil equivalent, **gCeq** - Gramme carbon equivalent **$kgCO_2eq$** - Kg CO_2 equivalent

Conversion coefficients for each type of fuel and electricity production, are used and published by OECD, IEA & National statistics (Table 1 & 2): therefore a comparison is possible. For products originating in France, Belgium, New-Zealand and Brazil, different conversion factors are needed.

Electricity produced	nuclear energy in electricity production in 2001[(1)]	Energy equivalent conversion factor	Carbon equivalent	CO_2 equivalent
	%	goe/kWh [(2)]	gCeq/kWh [(3)]	gCO_2eq/kWh
in France	80	226	23	84
in UK	20	121	124	455

Table 2: Conversion factors for electricity use

[(1)] source : "Bilan Carbone - guide des facteurs d'émissions version 5.0, ADEME 2007, p 195
[(2)] obtained by multiplying the % of nuclear with the 'international conventions' on conversion factors (nuclear conversion factor is 261 goe/kWh and other primary energy sources 86 goe/kWh) AIE 2006
[(3)] source : "Bilan Carbone - guide des facteurs d'émissions version 5.0, ADEME 2007, p 34

Results of data collection and analysis for the UK apple supply chain

An initial stage for each case study has been the preparation of a supply chain map showing the key physical movement details (Figure 1).

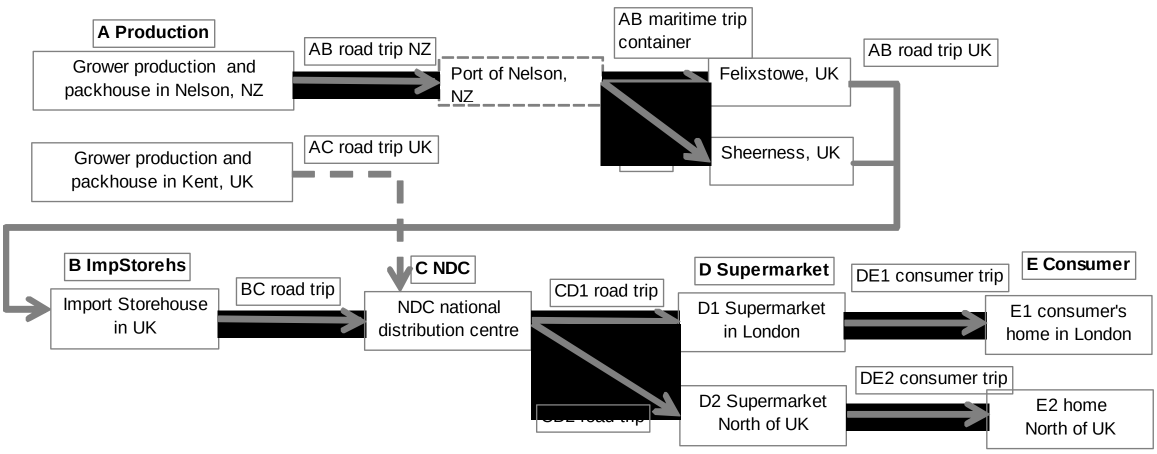

Figure 1 Shape of import and home produced apple supply chains in UK

Figure 2 shows a number of comparisons between apples that have different points of origin and destination.

First evidences from these data (Figure 1 and 2) are:

- High efficiency of road freight transport in UK compared to maritime and final consumer legs
- UK production and New Zealand production show less difference than expected
- Consumer trips have a high influence on the total supply chain energy. The consumer trip for London is assumed to be with 10 kg load and 3.5 km distance one way by car, and for lower density area like Scotland, it is 10 kg load and 7 km one way.
- Scotland shopping trip use more energy than the whole supply chain before, even if we include production.

Results for French apple supply chain

The data collection for France confirms the UK findings (see Figure 3). The main difference between the French and UK import supply chain is the lack of charter vessel use in France, with all companies surveyed using international container shipping only. The final consumer trip for Paris suburbs area is slightly less energy intensive than the London trip. The final consumer trip in Limousin (18 km one way, 30 kg load, 81 goe/kg apple) shows rather high energy consumption, due to a longer mean shopping trip distance.

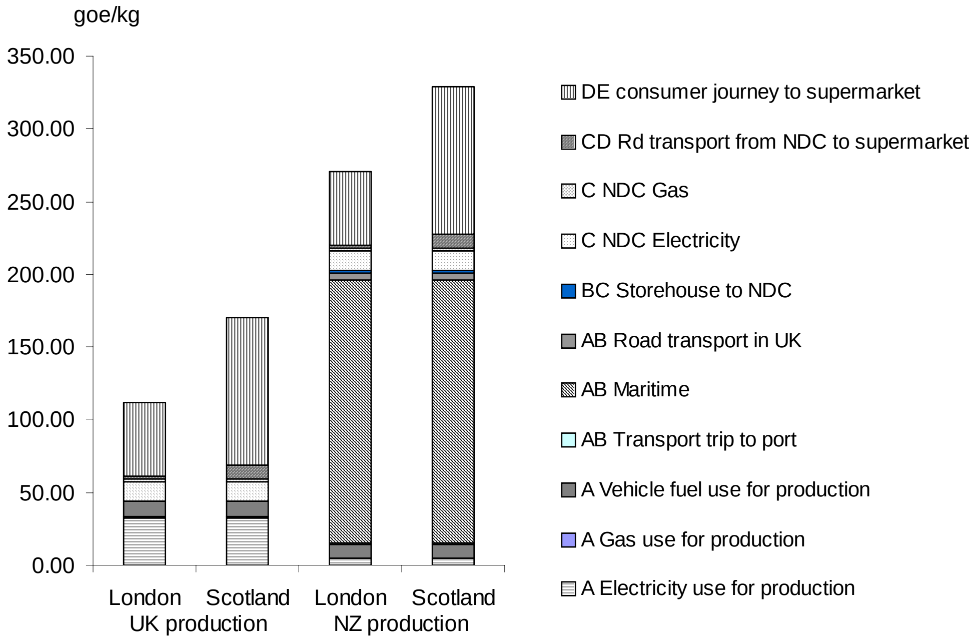

Figure 2: Comparison of Import and UK apple supply chain energy efficiency

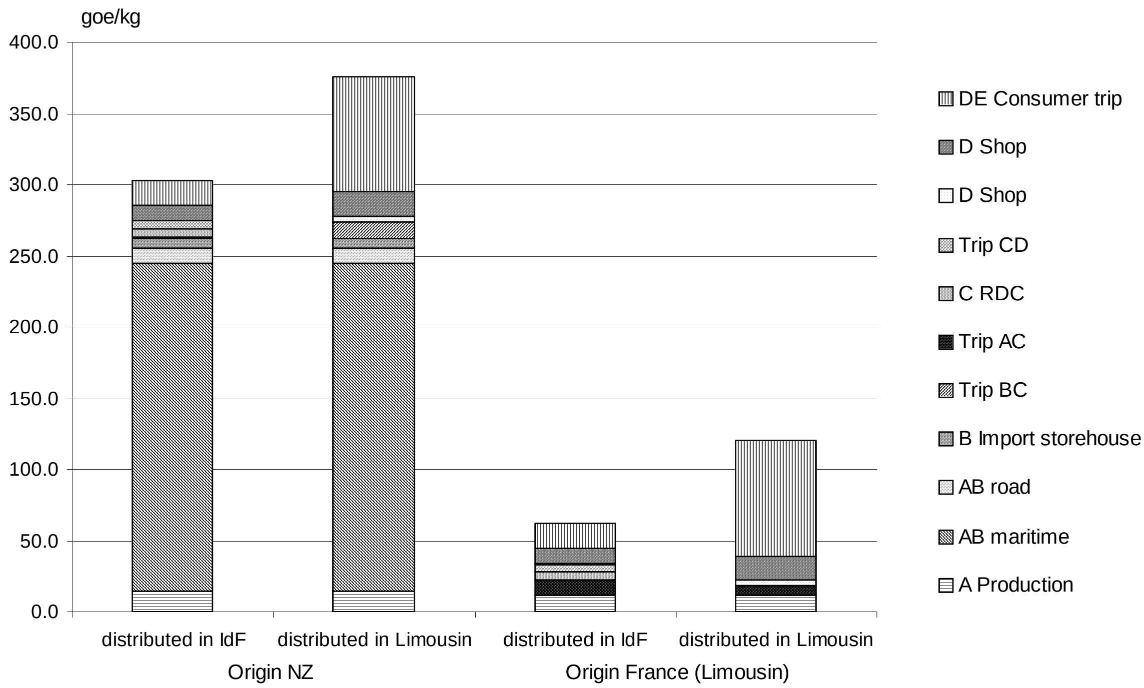

Figure 3: Energy use in the apple supply chains for France

Furniture supply chain in UK: the example of the chest of drawers

For furniture distribution, the final consumer trip is more complicated than for food purchases, this makes this case interesting for the supply chain analysis. For example, the consumer may go to view the product in several stores before the final purchase.

In the UK case the origin of the product 'pinewood chest of drawers' is a plant in Brazil. It is distributed by a major retailer in UK. The shopping trip includes one visit to the shop by car, with following average trip characteristics: 16 miles return trip for London, 24 miles incl. return for Scotland, 25 kg load, car fuel use is 8l/100km.

For this example of product, the average consumer trip uses more fuel per kg product than the maritime transport from Itajai (Brazil) to Felixstowe (UK) (Figure 4).

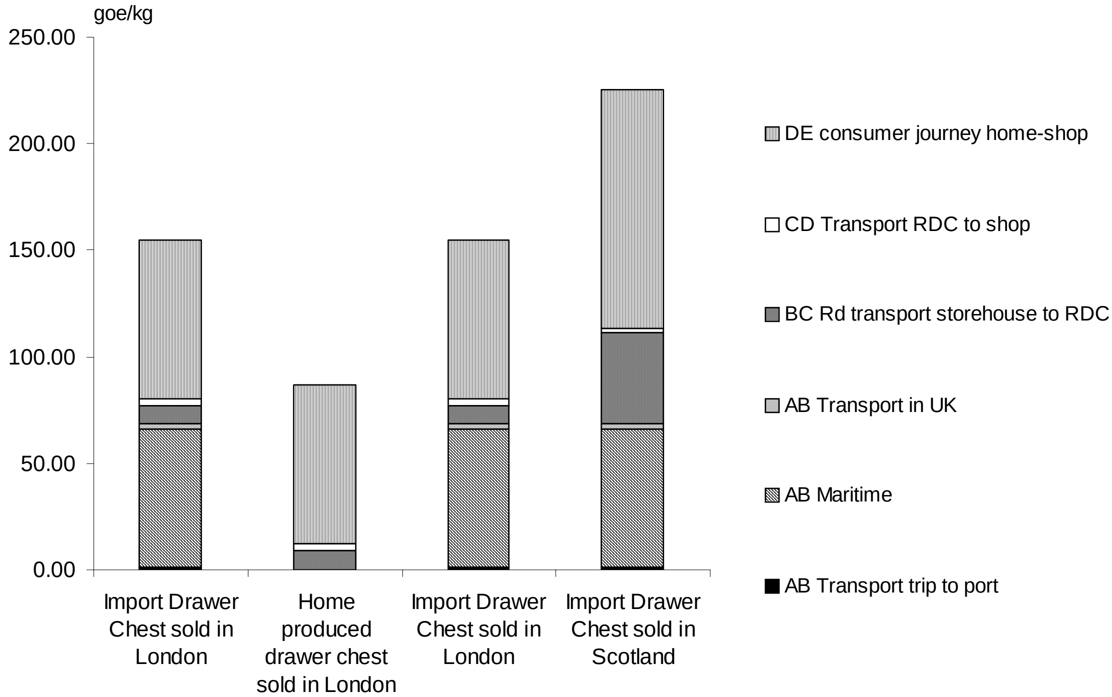

Figure 4: Import and home production, high density vs. rural distribution for drawer chest

The consumer trip

At the end of the supply chain it is also apparent that the consumer trip shows some important effects on the consumption of energy within the total chain. However, this trip depends very much on the home-shop distance, and on quantities transported by the consumer (Beauvais 2005). Figure 5 summarises our finding for the buying trips (for the chest of drawers) in UK. Home delivery, for instance, is not always the most efficient solution.

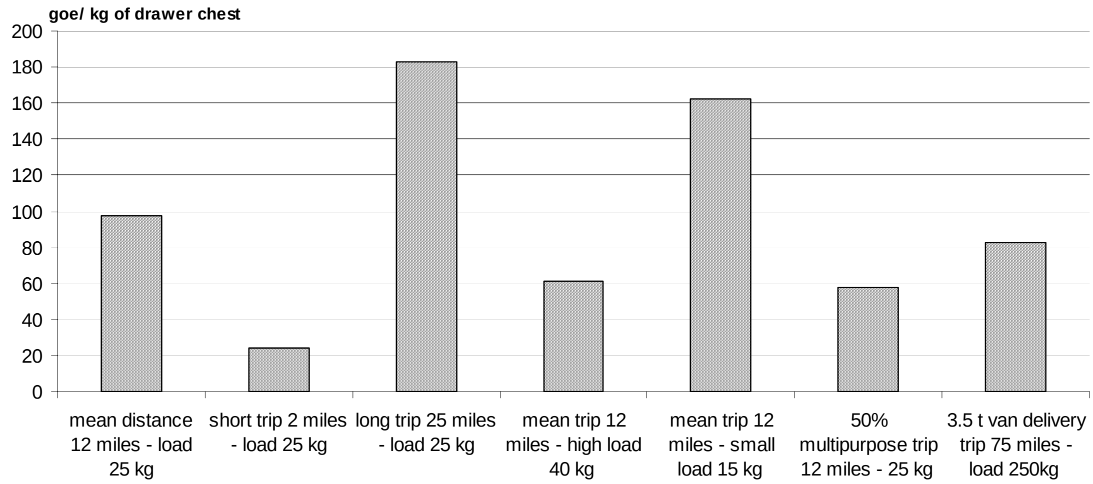

Figure 5: Sensitivity of the final shopping trip leg to assumptions and consumer choices

Note: (i) Standard trip assumption: 10 miles is the mean distance home-shop and 25 kg is the mean load for one buying trip (Future foundation, 2007). (ii) 75% of Londoners use a car for furniture shopping trip (Future Foundations 2007). (iii) Multipurpose trip: from consumer's workplace to shop to home assumes 25% of total distance is empty

Conclusions

For both types of supply chains, food and furniture, two steps dominate by far the other ones in supply chain transport energy use: Maritime shipping and final consumer shopping trip. In the case of maritime transport the main point is that despite the high energy efficiency per tonne-kilometre for maritime transport when compared with other modes, the overall distance travelled is large and therefore the total transport energy requirement is comparatively large compared with more locally sourced products.

For the consumer trip it is clear that the nature of the assumptions about the trip and the way in which energy allocations are made have a major impact. If the consumer makes a 'combined' trip and energy use is apportioned according to the various trip purposes then the energy consumption attributable to the purchasing activity will be reduced. In some cases it could be argued that this figure could be zero (for example when a consumer purchase an item on their way home from work with no additional transport requirements). This highlights the need for greater understanding of consumer shopping trips and the extent to which trip behaviour could be influenced by providing more information about the energy implications. In a recent Logistics Director Forum meeting (LDF, 2008) the lack of ability to directly influence the consumer was noted. Clearly there is the opportunity for collaborative work between travel behaviour researchers and those more directly concerned with the supply chain.

The desirability of common measures, models and standards has also been noted (LDF, 2008). The approach described in this paper enables comparisons to be made between different supply chain configurations in terms of the energy requirements and the options for reducing energy use within transport activities in the chain. By identifying the most important transport activities in terms of energy uses it helps to ensure that that attention can be focused on the key transport decisions. There is a need to balance the amount of management time and the cost of data collection with the potential opportunity that exists to change the supply chain and thereby reduce the total energy requirement. The approach discussed in the paper seeks to provide a standard and robust methodology that can be applied across countries and product types and that relies on a relatively straightforward data collection approach.

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