Energy efficiency and greenhouse gas emissions of different supply chains: a comparison of French, UK and Belgian cases.

Christophe Rizet[1]
Michael Browne[2]
Jacques Léonardi[2]
Julian Allen[2]
Eric Cornélis[3]

[1] INRETS, FR
[2] School of Architecture and the Built Environment
[3] TRG-FUNDP, BE

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ENERGY EFFICIENCY AND GREENHOUSE GAS EMISSIONS OF DIFFERENT SUPPLY CHAINS: A COMPARISON OF FRENCH, UK AND BELGIAN CASES

Christophe Rizet
INRETS/DEST, F
Michael Browne, Jacques Léonardi & Julian Allen
TSG, University of Westminster, UK
Eric Cornélis
TRG-FUNDP,BE

1. THE SUPPLY CHAIN APPROACH FOR ENERGY QUANTIFICATION

Producers, retailers and third-party logistics providers are increasingly interested in carrying out energy assessments taking into account all the legs of the supply chain (LDF, 2008). Such an approach is presented in this paper. This concern is due to sensitivity to the problems of climate change and CO2 emissions as well as to rising energy costs. Some companies are even starting to adopt such approaches as part of their Corporate Social Responsibility (CSR) agenda. This paper illustrates that an assessment approach based on the supply chain is useful in comparing the energy use implications of different strategies which could be followed by companies.

This paper is based on research which formed the second step of a project on “Supply Chain, energy and GHG” (this second step of the project will be referred as “Supply Chain 2” in this paper). “Supply Chain 2” is being carried out by INRETS (France), the University of Westminster (UK) and the University of Namur (Belgium) for ADEME (the French Environment and Energy Management Agency). The final objective of this supply chain project is to provide a contribution to the discussion on the carbon footprint of a product by comparing different supply chains, measuring their energy content in a standardised way, quantifying the transport specific energy consumption steps in the considered supply chain and identifying potential strategic logistics choices and options that can lead to reduced energy use. Importantly, the study also considers the consumer shopping trip and, if relevant, compares it to a home delivery alternative. The specific objectives of ”Supply Chain 2” are to test the results of the first step on new products and new countries and to focus in more detail on the consumer trip which had been found to be an important part of GHG emissions within the whole chain.

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 carried, type of vehicle used, 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 taken into account and about the system boundaries drawn. In some cases like the Life Cycle Analysis (Browne et al., 2005), or the French carbon balance (Ademe, 2007), the complete chain of all suppliers of a company has to be assessed. However, the need for efficiency leads us to the choice of a survey method assessing the energy used from the producer to the consumer, so focusing more on freight transport movements than on other specific steps of the "complete" chain like agricultural production or recycling or product disposal (Rizet 2007).

More precisely, after this first section on the whole context of the research, this paper provides, in the second section, a brief description of the methodology. Then Sections 3 and 4 will present the results for two studied products: apples on one hand and a chest of drawers on the other hand. As already mentioned, the last leg of the chain, the consumer trip, was also an important focus of "Supply Chain 2"; it will be presented in Section 5. And finally some conclusions will be outlined in Section 6.

2. STANDARDISED METHOD

Since a central objective of "Supply Chain 2" is to obtain a complete figure of the energy content of a "typical" supply chain by focusing on specific products, this project considers fresh food products (apples and tomatoes) and items of furniture (chest of drawers and book case). 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 which could lead to reduced energy consumption may be common across different product categories. Applying a standardised research method should lead to efficient data collection, this means relatively simple and not time consuming for the involved companies. In line with these principles, the surveyed companies were mainly market leaders in the chosen product categories and the cases study focused on products sold in high volumes and generally available all the year round (although the sourcing may change with fresh produce to accommodate seasonality issues).

In the applied method, different types of transport energy, used in the supply chains, have been included such as diesel for goods vehicles or bunker fuel oil for ships. Fuel, gas and electricity data have also been collected for storehouses, production plants, distribution centres and shops. Moreover, at all stages, data for tonnage of the products grown, manufactured, transported, stored or distributed was collected together with the energy use data. For this collection, the time unit considered was the year (i.e. how many tonnes had been shipped or stored in a year).

All figures for energy consumption have been converted into 'grammes of oil equivalent' (goe) using coefficients defined in Ademe (2007). A gramme 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 accross different energy sources. The calculation differentiates the energy consumed in buildings (warehouses, stores and shops) or for transport. For buildings the general formula is:

$$E_{cp} = \frac{(L \times 845) + (E_e \times 121) + (E_g \times 86) + (E_f \times 845)}{V}$$

where:
Ecp = Energy consumption per product unit, in goe per kg
L = Annual fuel use (diesel) for all “handling” vehicles in litres (845 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 propulsion purposes in kWh
Ef = Annual fuel use for heating in litres
V = Annual volume of handled products in kg

Applying the same principles and factors (Table 1) to a road freight transport leg between two sites is fairly simple. The companies provide data on fuel use (miles per gallon in the UK, litres/100km elsewhere) distance, load, truck type and empty runs. From these data, consumption is calculated using:

$$Ecp = \frac{(L \times (D \div 100) \times E \times 845)}{Q}$$

where:
Ecp = Energy consumption per product unit, in goe per kg
L = Mean fuel use (diesel) computed from all vehicles in the fleet (in litres/100km)
D = Distance travelled between origin and destination of the supply chain leg
E = Empty running factor (1 = no empty running; 2 = one empty return trip etc)
Q = Load per trip in kg
845 = Energy conversion factor for diesel fuel (Table 1, line 1)

For sea transport, the principle is the same as for road. However, other specific indicators are needed: port calls and shipping line route, nautical miles between 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	= kg	= goe	= kgCO_2eq
Diesel	1	0.845	845	2.951
Petrol	1	0.755	791	2.841
Heavy fuel oil	1	1	952	3.553

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

Notes: **goe** - Gram oil equivalent, **kgCO_2eq** - Kg CO_2 equivalent

According to IEA (2006) the nuclear conversion factor is 261 goe/kWh for nuclear electricity and 86 goe/kWh for other primary electricity energy sources. A conversion coefficient has been estimated per country, using these coefficients and the share of nuclear electricity in each country. The resulting coefficient for France, Belgium,and UK are in table 2.

Electricity produced	nuclear energy in electricity production in 2001	Energy conversion factor	CO_2 equivalent
	%	goe/kWh	gCO_2eq/kWh
In Belgium	60	191	268
in France	80	226	84
in UK	20	121	455

Table 2 : Conversion factors for electric energy in different countries

3. FRUIT SUPPLY CHAIN : THE EXAMPLE OF THE APPLES

Even if a large number of supply chains have been analysed throughout “Supply chain 2”, we will only illustrate the methodology and the results by presenting some of them in this paper: some for apples in this section and some for chest of drawers in the next one.

First of all, an initial stage for each case study has been the preparation of a supply chain map showing the key physical movement details. Figure 1 summarizes this map for apples...

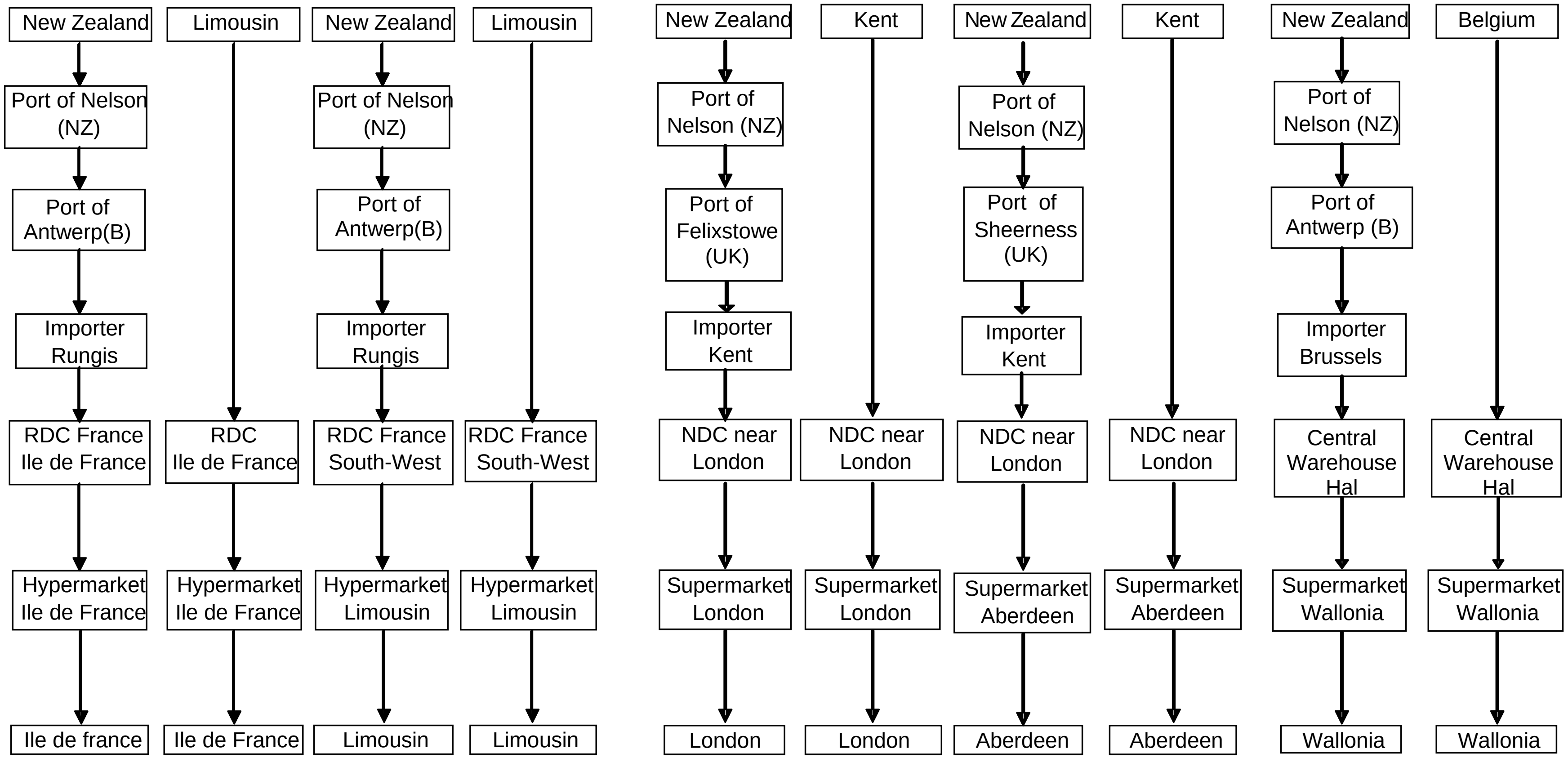

Figure 1 : Apple supply chains examined in the study

Focusing now on some of these chains, Figure 2 shows the energy use in the selected supply chains (identified in Figure 1). The aim of this figure is to highlight the differences in energy consumption between imported apples and those produced within a national market.

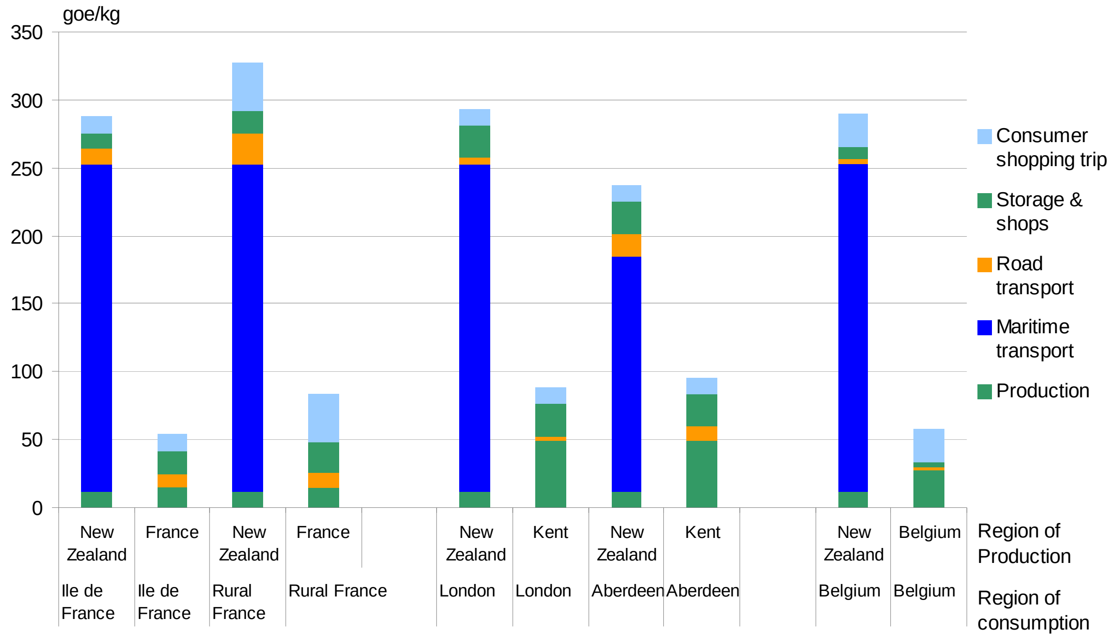

Figure 2 : Comparison between import and "domestic" apple supply chain energy efficiencies (apples sold in hypermarket or large superstore)

The results from Figure 2 reveal several points. First, it is clear that even though maritime transport is very energy efficient per tonne-kilometre the distance involved when New Zealand apples are bought results in much higher transport energy use for imported apples than in the case of locally produced apples. Secondly, the importance of the consumer trip in terms of transport energy is also evident with considerable variation between densely populated areas and those with lower density (e.g. rural France); we will come back on this point in Section 5. Thirdly, the analysis can also be used to illustrate the difference induced by vessel type choice. Apples shipped from New Zealand to the UK could be carried by container vessel or by more specialised refrigerated bulk vessel on charter. So, in the case of apples brought from New Zealand to Aberdeen transport took place via the UK port of Sheerness with a specialist vessel and this resulted in a lower energy use per kg of apples than for the apples sent from New Zealand to London in a container ship.

4. FURNITURE SUPPLY CHAIN: THE EXAMPLE OF THE CHEST OF DRAWERS

Within the "Supply Chain 2" research two types of furniture product were investigated – namely a chest of drawers made of pine and a book case made of particle board but in the following discussion the focus will only be on the pine chest of drawers. Figure 3 illustrates the different stages in the supply chain for this furniture.

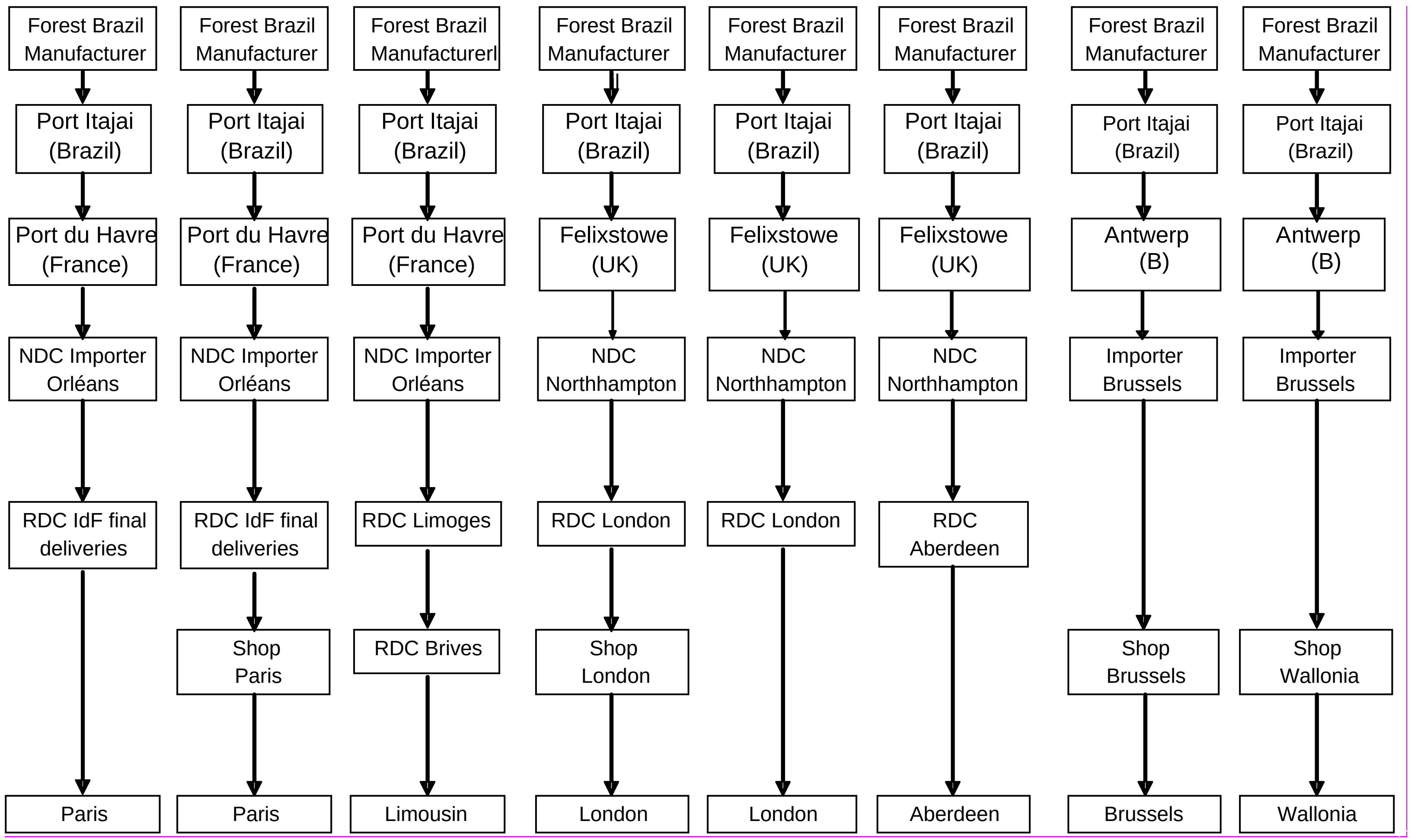

Figure 3 : Chest of drawers supply chains examined in the study

Figure 4 shows that the final consumer trip is far from being negligible in the supply chain. Indeed, for furniture distribution, this part of the chain could be more complicated than for food purchases: for example, the consumer may travel to have a look on the product in several stores before the final purchase which makes this case interesting for the supply chain analysis..

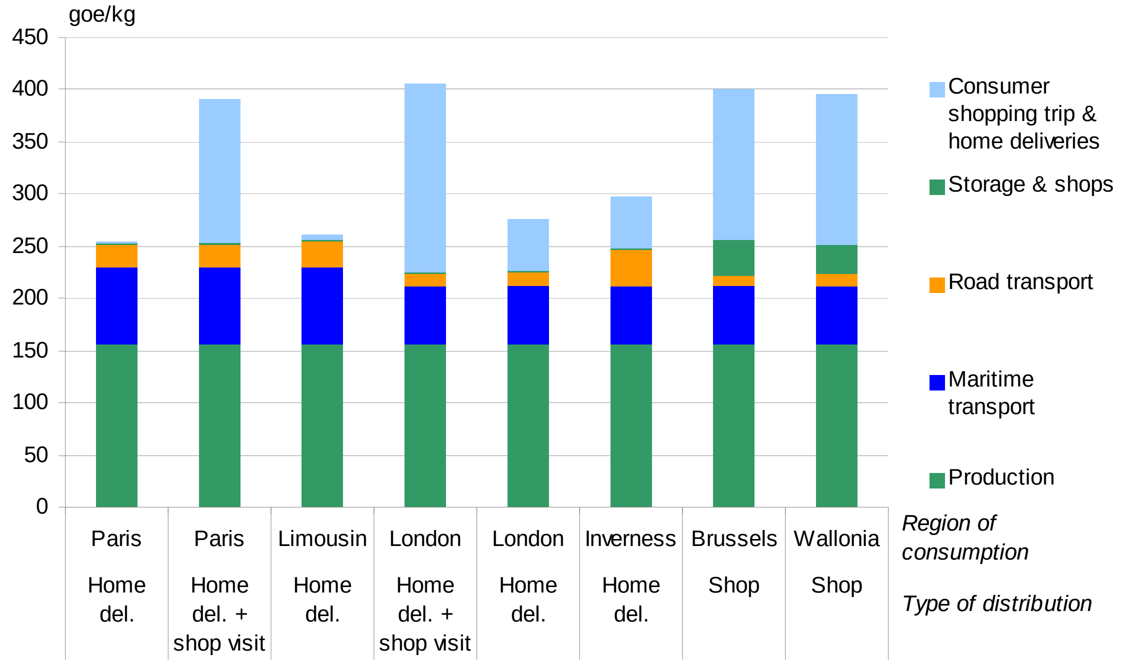

Figure 4 : Comparison of the supply chain energy efficiencies for a pine chest of drawers

From the results shown in Figure 4, we could highlight a couple of features. First, in this case, we have introduced an estimate of the energy consumed in production, which is normally not included in our supply chain approach but which illustrates a key point of the life cycle consumption: energy consumed in production is somewhat more important than the logistical part of the supply chain (transport + storage and shops) up to the shop. *

On another hand, some of the supply chains include a consumer shopping trip, which has been estimated with our online consumer survey and, when relevant, summed up with the home delivery (and presented in the Figure). For those chains with a consumer trip, this upper part in the Figure is the most important of the whole supply chain.

And finally, even with a maritime intercontinental transport, the logistical part of the supply chain, i.e. transport and storage and shops consumption, is generally not the most important part of energy consumption in the whole production and supply chain.

5. THE CONSUMER'S TRIP

As already mentioned in the previous sections, it seems apparent that, at the end of the supply chain, the consumer's trip causes some important effects on the energy consumption within the total chain. However, the impacts of this trip depend very much on the home-shop distance, and on quantities purchased by the consumer (since we measure the consumption of energy per kilo of product).

For taking into account and estimating these impacts, a web based survey was undertaken in France, Belgium and UK. It aims at surveying consumers on their purchasing trips related to the studied products. We will now outline the main lessons that have been drawn from this survey.

The on-line survey provided information on consumers' travel behaviour for trips made to purchase products including details on the distance travelled to view products (before actual purchase) and to shop. In addition, information was collected on the average weight of purchases as well as on the transport mode used for shopping. In total 1056 useful responses were obtained and this has a confident estimate to be made of the energy consumed for the shopping trip. Nevertheless, it should be noted that the diffusion of the on-line questionnaire through a strategy of 'viral dissemination' means that there could be some bias in the responses (e.g. too many answers from respondents who are above average education) and therefore care needs to be taken before widely generalising the results. However the obtained results provide some interesting and useful insights into the relative importance of consumer trips in terms of the energy use within the overall supply chain. The Table below summarizes energy consumption for the consumer trip according to country and type of distribution.

	Belgium	France (rural)	France (towns)	United-Kingdom	*All-together*
Supermarket in town	12,5	15,3	3,9	11,9	9,7
"Round the corner" shop	0,3	74,5	2,9	0,5	13,5
Hypermarket	22,8	35,2	12,7	19,8	21,8
Open air market	28,4	20,9	7,9	23,8	12,9
Direct sale from producer	28,5	100,8	0,0	69,5	37,0
Early fruits shop	14,3	45,1	6,5	0,0	24,0
Outlying supermarket	24,5	21,1	9,3	10,5	20,5
"Minimarket" in town	5,9	9,7	3,3	2,4	5,6
Alltogether	20,5	28,7	7,7	13,1	17,4

Table 3: Energy use for the consumer's trip - fruit and vegetables (goe/kg)

The consumer's trip energy consumption is quite different according to the type of distribution: from 6 goe/kg for the minimarket in town up to 24 goe/kg for early fruit shop and even 37 goe/kg for direct producer sales. We also note an important difference between rural (29 goe/kg) and urban (8 goe/kg) consumers in France.

There were fewer answers for trips related to buying a furniture product; this could be partly explained by the fact that this is a less common purchase. Therefore only a less detailed analysis can be made (see Table 4 below).

	B	F	UK	Alltogether
goe/purchase	4344	3573	2186	3746
goe/kg	139	115	77	121

Table 4 : Energy use for the consumer's trip – furniture (goe/kg)

Considering the Tables above it can be estimated that a consumer buying furniture uses more than 3 kilo oil equivalent (which equates to 121 goe per kilo of furniture purchased.) whilst purchasing a kilo of fruit or vegetables consumes only 17 goe which is significantly less. Such a difference is largely explained by the observation that people travel longer distances for furniture and that they don't hesitate to make several trips to look at other models/makes before the actual purchase.

6. CONCLUSIONS

For both types of supply chains, fruit and furniture, two steps dominate by far the other ones in supply chain transport energy use: maritime shipping and the 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 travelled distance is huge and therefore the total transport energy requirement is comparatively large in contrast to the requirements for more locally sourced products.

Concerning the consumer's trip it is clear that the nature of the assumptions about the trip and the way in which energy allocations are resolved have a major impact. If the consumer makes a 'combined' trip (i.e. a single travel with different or multiple purposes) and energy use is apportioned according to the various trip purposes then the energy consumption assigned 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 purchases an item on their way home from work with no additional transport requirements). This highlights the need for better understanding of consumers' shopping trips and the extent to which trip behaviour could be influenced by providing more information about the energy implications This clearly opens an opportunity for collaborative work between travel behaviour researchers and those more directly concerned with the supply chain.

The benefits of common measures, models and standards are clear. In such a direction, the approach described in this paper enables comparisons between different supply chain configurations in terms of energy requirements and across 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 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 for changing the supply chain and thereby reducing the total energy requirement. The approach discussed in this paper seeks to provide a standard and robust methodology which could be applied across countries and product types and which relies on a relatively straightforward data collection approach.

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