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Comparing Domestic versus Imported Apples: A Focus on Energy Use

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Abstract

Goal, Scope and Background. The issue of whether food miles are a relevant indicator for the environmental impacts associated with foods has received significant attention in recent years. It is suggested here that issues other than the distance travelled need to be considered. The argument is presented by illustrating the case for the provision of apples.

Materials and Methods. The effects of variability in primary energy requirements for apple cultivation and for other life cycle stages, seasonality (timing of consumption) and loss of produce during storage are studied in this paper, by comparing apples from different supplier countries for consumption in Europe.

Results. Data sources for primary energy use (PEU) of apple production are identified ranging from 0.4–3.8 MJ/kg apples for European and Southern American countries and 0.4–0.7 MJ/kg for New Zealand. This variability is related to different yields and producer management practices in the different countries. Storage loss may range from 5% to 40% for storage periods between 4 and 10 months, and this has a significant effect on the results (e.g. increasing the total PEU by 8–16% when stored for 5–9 months in Europe as compared with a no loss and no storage situation). The storage periods and related storage losses change markedly through the year for imported (i.e. non-European) versus European apples.

Discussion. The timing of consumption and related storage losses need to be included in the assessment, as this affects the order of preference for locally sourced versus imported apples. The variability in energy requirements in different life cycle stages, but particularly for the fruit production stage, is also significant in this comparative analysis.

Conclusions. Overall, it seems that there are similarities in the total PEU ranges for European and New Zealand apples during the Southern Hemisphere's apple season (European spring and summer). However, during the European autumn and winter (Northern Hemisphere apple season) PEU values are generally higher for apples imported from the Southern Hemisphere compared with European apples consumed in Europe. However, this latter observation may not hold true where apples for consumption in one European country are imported from another European country, because energy use for road transportation has a significant influence on the result.

Recommendations and Perspectives. Future studies comparing alternative sources of fresh produce need to account for ranges of data for the fruit production and storage stages, which reflect the seasonality of production.

Keywords: Apples; Europe; food miles; food storage; food waste; primary energy use (PEU); Southern Hemisphere; transport

Introduction

Recent publications on localisation versus globalisation of alternative food systems have highlighted some controversies related to the 'food miles' concept [1–5]. Food miles refer to 'the distance food travels from the farm to consumer' [1]. Blanke and Burdick [5] and Sim et al. [4] compare different sources for year-round supply of apples in Europe, concluding that the local (domestic) sourcing scenario results in more favourable results. Year-round supply of fresh produce reflects supermarkets sourcing strategies and consumer demands: according to recent research (Barry Hounsome, University of Wales, personal communications November 2006) over 70% of consumers in UK urban areas consider that they should have the choice of purchasing any product at any time of the year. This paper elaborates further on the issue of primary energy use (PEU) to deliver apples year-round in Europe, commenting on some critical issues that need consideration in comparisons of the primary energy requirements of domestic vs. imported food, namely:

1. variation in PEU for apple cultivation in different countries
2. timing of consumption and need for storage of apples
3. inclusion of consumer shopping preferences and other post-retailing processes

Assumptions concerning the above points are critical in a comparative analysis of different sources of apple supply for consumption in Europe. We discuss the three points numbered above in Section 1. Section 2 describes scenarios based on different seasons and supply countries to illustrate how modelling assumptions can affect the results in this type of analysis. Then, Section 3 describes how the variability in input data has been considered and propagated through the calculations, and Section 4 shows the energy use results for the different scenarios. In Section 5 we discuss the results and in Section 6 we draw conclusions about the choices available to consumers based on originating country and seasonality.

1 Aspects Affecting the Primary Energy Use of Apples

We use primary energy use (PEU) as an indicator for environmental impacts; PEU has demonstrated its adequacy in many cases as a screening indicator for environmental performance [6]. PEU includes all upstream energy use to deliver energy in e.g. electricity (from fossil fuels and nuclear plants) and fossil fuels. In this paper we analyse the PEU (expressed in MJ) related to the production and delivery of 1 kg apples to a European shop, excluding renewable energy.

1.1 Primary energy requirement for apple cultivation

Based on our own published [4,7–9] and unpublished research undertaken in the last few years, and other published studies [10–12], we consider 0.4–0.7 MJ/kg in New Zealand and 0.4–2.0 MJ/kg in European and other Southern Hemisphere countries as reasonable estimates for the minimum and maximum values of primary energy use for apple cultivation in the scenarios set out in Section 2.

1.2 Timing of consumption and need for storage of apples

The time of the year at which apples are consumed affects the relative comparison between apples from different countries due to the need for storage and/or transportation from overseas for out-of-season apples. Storage of apples results in extra energy use and possibly in loss of produce, which requires extra production at the cultivation stage. Obviously the need for storage depends on apple variety; while some authors claim that one can get in-season apples most of the year simply by using different apple varieties [13], the varieties most demanded in the European market (Royal Gala, Golden Delicious, Braeburn, Pink Lady...) have a narrower seasonal window and so require either storage or overseas supply.

We have considered a storage loss of 5% after 4 months' storage and a linear increase up to 25% loss after 10 months' storage. The variability in % of fruit loss can be expressed as a 5–15% minimum and a 10–40% maximum loss range over 4–10 months storage. Loss during storage means that the amount of apples produced needs to be recalculated in the study. Thus, if there is a 20% loss in storage, 1.25 kg apples must be produced at the farm in order to supply 1 kg of apples to the consumer. Therefore the energy requirement per 1 kg apples at the consumption stage increases accordingly.

We have considered that apples imported from the Southern Hemisphere are stored at the origin until they are transported for retail in Europe. However, there is a growing tendency to import the apples and store them in Europe (David Johnson, East Malling Research, personal communication). Hence more apples need to be transported to allow for storage losses in Europe, increasing the overall energy use (see below).

1.3 Consumer shopping and post-retail stages

Blanke and Burdick [5] included consumer shopping in the comparison of domestic versus imported apples. However, in general people do not travel to a shop solely to buy apples; they buy several items, and if apples are not available they will buy another fruit instead. Besides, all post-retail stages will be the same regardless of which apples the consumer chooses. Therefore we have removed this life cycle stage from the analysis.

It may be argued that it is interesting to assess whether post-retail stages are relevant or even dominate the overall picture of environmental impacts associated with the life cycle of food. However, for this to be achieved, all post-retail stages (transport to home, storage at home, cooking; waste management) should be included, rather than just consumer shopping.

2 Scenarios

In order to illustrate the influence of the above points on the results and conclusions, we calculate PEU for different scenarios of apple consumption in Europe, considering four possible supplier countries and four different months of consumption which represent the four seasons of the year. The different months considered determine the storage length, and thus the % of produce loss (Section 1.2) and the extra amount of apples that needs to be produced to supply 1 kg of apples in the shop. The following assumptions are made:

- In October most Northern Hemisphere apples are in season and can be found in the market; there are no storage requirements (apart from the initial cooling). Southern Hemisphere apples in European markets at this time of the year would have been stored for around 4 months.
- In January, European apples will have been stored for a few months (considered: 3 months), whereas Southern Hemisphere apples are rarely found in European markets at this time of the year due to their associated storage requirements (ca. 7 months) and competition with European apples.
- April is the month when new Southern Hemisphere apples begin to arrive to European markets in large numbers, and will continue to be in-season until June–July. European apples sold at this time of the year would have been stored for ca. 5 months from November.
- Apples sold in August in Europe require short storage times when coming from the Southern Hemisphere (considered: 4 months), or about 9 months if produced in Europe.

Four different suppliers have been considered, which may be described as (see Table A1 in the Appendix for details):

- EU1: European apples consumed in the country of production (e.g. apples produced and consumed in the UK).
- EU2: Apples produced in a European country different to the one in which they are consumed (e.g. Italian apples consumed in the UK). The basic difference with the above scenario is the transportation distances considered.
- NZ: Apples produced in New Zealand and consumed in Europe. New Zealand is a traditional apple supplier. Apple producers are highly skilled and market oriented, which, together with favourable climate and soil conditions results in efficiency gains and lower PEU per kg of apples (Section 1.1).
- OSH: Other Southern Hemisphere countries, including traditional and emerging suppliers of apples for the Northern Hemisphere (e.g. Chile, Argentina, South Africa, Brazil). PEU per kg of apples is more variable and similar to that for European producers (Section 1.1). Shipping distances are shorter than for NZ, although transport by truck to the port may be longer and/or more variable than for NZ.

3 Accounting for Variability in Primary Energy Use Data

In order to determine the potential variability in the total primary energy use (PEU) for the provision of apples, the variability in each parameter used in the calculation of the total PEU (see Table A1) was represented by a probability distribution. Given the nature of the information at hand (a few representative parameters from a range of studies and

expert input), it would have been appropriate to assign a uniform distribution to each of the parameters based on the estimates of the minimum and maximum values (see footnotes to Table A1, Appendix, for details of how these estimates were obtained.) However, of particular interest for this study was to illustrate the potential ranges of values for the various parameters alongside the values used in earlier studies, and to determine whether the conclusions made would differ from those where only single values for each parameter were used (as was the case in [4,5,7–9]). For illustrative purposes, the relevant values used by Sim et al. [4] and Milà i Canals et al. [8] for the cultivation stage and Blanke and Burdick [5] for the other life cycle stages were thus considered to be good representative values for each parameter within a range spanned by the estimates of the minimum and maximum values. Triangular distributions were thus assigned to the parameters where the relevant values of [4,5,8] were considered to be the mode of the triangular distributions. The mode is the value that has the highest probability density [14]; hence there is a reasonable basis for a correspondence with the 'representative values' for the parameters. The parameter values were then propagated through the primary energy use calculation using a random sampling technique (Median Latin Hypercube sampling with 100,000 samples) to yield a range of potential values for total PEU. Note that the study was also done using uniform distributions. The shapes of the probability distributions for the total PEU (after propagation of the uncertainty) are then also uniform (compare this to Fig. 1). However, the conclusions of the study, which are based on the full range of potential values (rather than on the median or the percentiles) remain the same. The results obtained using the triangular distributions are retained here to illustrate the importance of, and particularly the power of, quantitative approaches to the consideration of

uncertainty in LCA and related studies (e.g. footprints, food miles, etc.), the use of which is not common. It is the intent that this methodological illustration be of value to those who have better quality of information on which to base estimates of probability distributions. See [14] for detailed information on how to estimate probability distributions.

4 Results

The total PEU for each of the four months and each of the four scenarios is represented in Fig. 1 as 'box and whisker plots'. These represent the median values, the range between the 10th and 90th percentile (i.e. 80% of the possible values), and the highest and lowest expected energy use values for apples in each scenario, considering the variability in the input data. Table A2 (Appendix) shows the detailed results for PEU in each life cycle stage for each scenario.

The potential ranges of PEU values overlap for European and Southern Hemisphere apples in the months of April and August. It is notable that European apples produced and consumed in a different country (EU2 scenario) may have larger energy consumption than Southern Hemisphere ones (both OSH and NZ scenarios), particularly in the August scenario when storage losses increase energy from apple cultivation due to required overproduction.

However, the overlap in the ranges of energy use values is not so evident in the months of October and January; indeed, when apples are in season in Europe it seems reasonable to suggest that it is more favourable from a PEU point of view to eat domestic produce. However, apples from other European countries (EU2) may have energy requirements overlapping out-of-season apples shipped from the Southern Hemisphere (this is more so the case in October than in January). It is notable

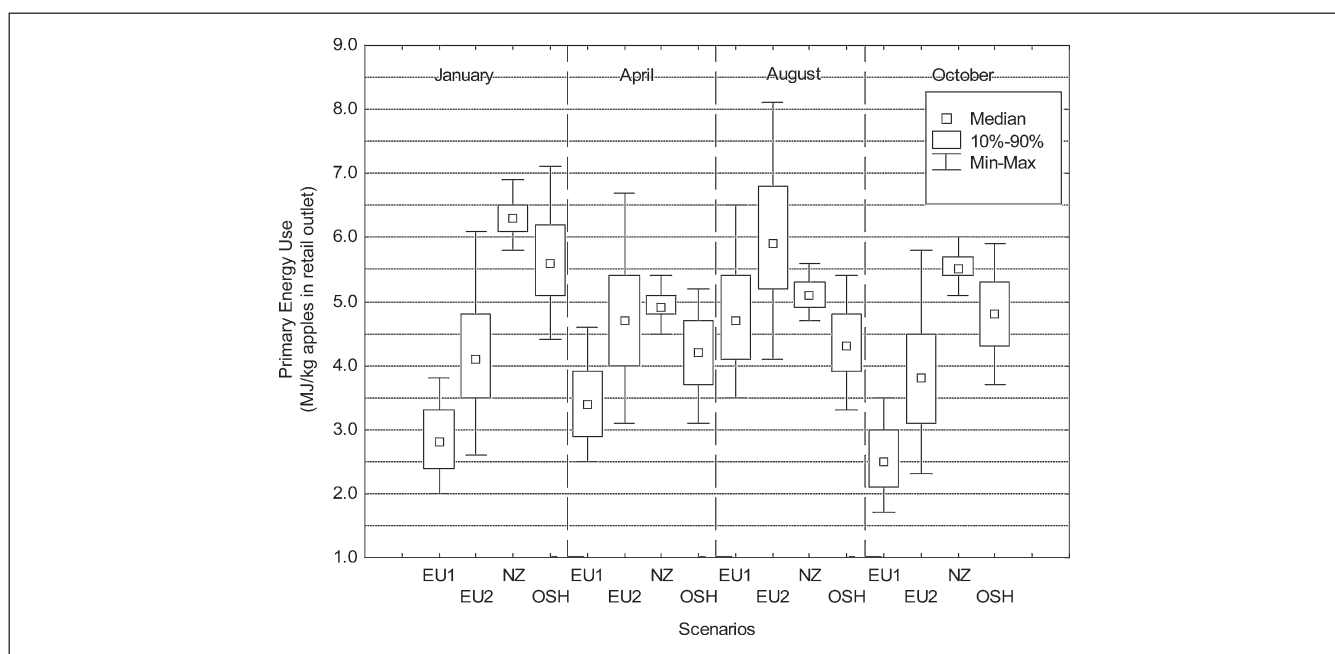


Fig. 1: Ranges of primary energy use per kg of apples from European and Southern Hemisphere suppliers for the different seasons, after propagating the variability in Table A1. EU1: Consumption of apples in the same country of production. EU2: Consumption of apples produced in a European country different to the one in which they are consumed. NZ: Consumption in Europe of apples produced in New Zealand. OSH: Consumption in Europe of apples produced in Other Southern Hemisphere countries

that the energy requirements for Northern vs. Southern Hemisphere apples are furthest apart during the winter (January); this is due to the fact that energy requirements for storage have still not grown significantly in Europe (3 months' storage), whereas storage loss has taken its toll on Southern Hemisphere apples. In this situation, it may thus be said that the effect of storage loss for longer periods of storage has a bigger effect than the energy use for storage.

Fig. 1 also provides some hints about the main sources of uncertainty. It is evident that the spread of values for NZ scenarios is much narrower than that of other scenarios. The main reason is that PEU values for apple cultivation are less variable in New Zealand studies, and variability in this parameter dominates the uncertainty in all other scenarios. In EU2, the variability in transportation distances also has a large effect on the spread of the values, resulting in the longest boxes and whiskers for this scenario.

Table A1 does not consider variability for all of the parameters (refrigeration; transportation in reefer; packaging). After considering a $\pm 40\%$ variation in these parameters (comparable to the variability in the parameters for which data was available), the general conclusions with regard to consumption of apples in the different European seasons remain valid, although there is greater overlap of the ranges of potential values for the total PEU for the different scenarios considered.

5 Discussion

Transportation to Europe by ship is the largest single contributor to PEU of non-European apples (46–59% and 27–36% of the possible energy use for New Zealand and OSH countries respectively, depending on the season). Furthermore, truck transport distances may vary largely depending on the country of origin and are a significant share of the cradle to retail PEU of apples, contributing 7–14%, 27–42%, 8–10% and 9–12% to the EU1, EU2, NZ, and OSH scenarios respectively. When apples are transported between European countries (EU2), the energy use of transportation raises total energy intensity of apples to levels closer to those of apples from Southern Hemisphere countries, particularly in Europe's spring and summer. From the data assessed in this paper, it is not clear that a scenario where all apples are produced and stored in the country of consumption will necessarily be better than a combination of Northern and Southern Hemisphere suppliers, as suggested by Blanke and Burdick [5] and Sim et al. [4].

However, it should be remembered that, from the consumer's perspective, informed choices between alternative apples in a shop are limited by the information available at the time of purchase. For example, the consumer cannot choose between apples based on their site-specific yields or production practices. In fact, the consumer's choices are limited to variety, originating country (in some retail outlets), type of packaging, and organic versus integrated/conventional production. It needs to be highlighted that current market trends show a growth in sweeter apple varieties such as Pink Lady, which can only be grown in countries offering particular conditions. E.g. Pink Lady cannot be grown in the UK, and thus for this variety EU2 is the closest scenario possible from a UK perspective. If retail packaging was included, this could influ-

ence the results to a large extent. Apples may be sold packed or loose regardless of their origin, and a consumer choosing apples according to their packaging rather than their origin might have more influence on the related PEU. Significant differences in PEU for organic vs. integrated apples are expected [7], which might be relevant in this type of comparison.

In addition, the mode of transport needs to be considered; while shipping tends to be very energy efficient, air freighting of food is increasing rapidly [1], and its environmental impacts tend to be larger than the primary energy used. The total radiative forcing due to aviation is probably some three times that due to the carbon dioxide emissions alone [15]. Apples are not commonly air freighted, but this latter comment might be particularly relevant for more perishable types of produce.

The way in which system boundaries are set also determines the comparative calculations of PEU. Consumers decide how to transport, store and cook (or not) apples at home. If cooking activities were relevant and included in the assessment, the variability in the PEU introduced by different cooking appliances and practices (e.g. gas vs. electric ovens; opening the oven door while roasting; old vs. new appliances; etc.) might be more crucial for the final results than the product's origin.

Finally, many other aspects in addition to energy use should be considered in an analysis of imported versus domestically-sourced fruit [3,5]. Apart from those mentioned in [3,5], the overall eating quality of local apples stored for lengthy periods compared with recently harvested apples imported from the Southern Hemisphere may also be relevant. Some environmental impacts tend to be dominated by agriculture-specific field emissions (e.g. eutrophication); differences in agricultural practices between countries could thus be more apparent if such impacts were included in the comparison. In addition, the economic implications of fruit exports, particularly for developing countries, should not be underestimated [16]. A fuller sustainability assessment using a life cycle framework would draw together these different aspects and provide more insights into the trade-offs associated with the choice of origin of foods (see e.g. [16, 9, Chapters 4–6]).

6 Conclusions

As concluded by Sim et al. [4], it is preferable from a PEU perspective to eat domestic apples when they are in season in the country of purchase and stored for shorter periods of time (i.e. 4 months or less). Here, 'domestic' refers to the 'same country of production'. When longer distances are involved (e.g. transportation between European countries) there is too much variability in energy use to reliably suggest that 'European apples' are less energy intensive than Southern Hemisphere ones. At other times of the year (the European spring and summer), consumers purchasing in accordance with this localisation strategy may or may not be purchasing apples with a lower life cycle PEU, depending on a number of factors (including production practices at the orchard, wastage during storage, and truck transportation distances). The data shown in this paper suggest that both variability in data resulting from production practices at the originating orchards and temporal aspects (seasonal-

ity and hence length of storage and wastage) affect the results, and thus the conclusions that can be drawn from the analysis. As the length of storage is relevant in the comparison of energy use between European and Southern Hemisphere apples, recommendations should be season-specific.

In conclusion, this type of comparison is very useful for providing insights into the environmental preference of different sourcing options, but it is difficult to make general recommendations because of the variability in data and characteristics of different food products. Particularly, specific farming practices introduce significant differences in PEU, in addition to those associated with varying transportation distances. The conclusions on environmental preference based on PEU depend on the season and the storage loss considered.

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Appendix

Variations in Primary Energy Use (PEU) for Apple Cultivation

From our own published [4,7,8,9] and unpublished research undertaken in the last few years, we have calculated values for apple cultivation on specific farms in various European countries between 0.4 and 3.8 MJ/kg. For New Zealand, we have calculated values between 0.4 and 0.5 MJ/kg based on data from three integrated production farms [7]. Another study gives values of ca. 0.6 MJ/kg, 0.5 MJ/kg and 0.4 MJ/kg for apple cultivation in France, Sweden and New Zealand respectively [10]. An average PEU of 1.2 MJ/kg apples at the farm gate is reported in 12 Swiss apple farms [12]. Using data provided by Reganold et al. ([11] and personal communication during July 2006) we have calculated a PEU of ca. 0.9–1 MJ/kg for apple orchards in the USA. If the early years of the orchard, with no or very low yield, are included, the energy use increases to 1.2–1.3 MJ/kg apples. Based on these data, it seems that values above 2.0 MJ are unusually high, and are usually correlated with particularly intensive use of agrochemicals and/or machinery.

This wide variability is partly due to the large variations in yields per hectare that are found between different farms, differ-

ent countries, and different years. The variability between farms may be very big due to different micro-climates; soil types; other geographical features related to location; producers' decisions (e.g. picking only the fruit that may be sold at a higher price), etc. Yields also vary enormously between countries. FAOSTAT [17] give an average apple yield in Germany and New Zealand of 27.1±6.6 Mg/ha and 37.6±4.8 Mg/ha respectively for the period 1994–2003. The variation of these figures suggests the magnitude of variability between farms. Yields also vary depending on the fruit quality considered. Milà i Canals et al. [8] only consider the yield of apples intended for direct human consumption because they provide 94–99% of the crop economic value. Energy use expressed in MJ/kg would be smaller if process apples were included in the yield (ca. 0.31–0.38 instead of 0.4–0.5 MJ/kg). Variations in yield between 'good years' and 'bad years' are also relevant; the energy inputs per hectare may not vary significantly whereas yield and therefore energy use per kg of apples does. Variability in yield thus explains partly the wide range in energy use per kg of apples in the cultivation stage and should be considered explicitly in future studies assessing PEU for crop productions.

Wastage During Apple Storage

Wastage of apples during storage may start to be significant at about four months of storage. Although there is large variability, wastage could be 15 to 20% over a five month period, increasing with increased length of storage (up to 40% or more at 10 months, [4]). The progression of this loss is exponential rather than linear [9, p. 40], but for simplicity we have assumed a loss of 5% after 4 months' storage and a linear increase up to 25% loss after 10 months' storage. The variability in % of fruit loss can be expressed as a 5–15% minimum and a 10–40% maximum loss range over 4–10 months storage. Loss during transportation from the Southern Hemisphere to Europe is negligible thanks to good temperature control on board and shipping times which are often less than four weeks; this issue can thus be ignored (Table A1).

Results

Table A2 shows the primary energy use (PEU) in the different life cycle stages for the different scenarios. It presents the median, minimum and maximum values. Due to the propagation of range of potential values for each parameter through the calculations (as explained in Section 3), the median value would not coincide with deterministic calculations using the representative values expressed in Table A1, neither would the totals in Table A2 result from adding up the numbers in the tables.

In the EU1 scenario, Table A2 shows that the same 3 items are always the main single contributors to energy use for apple delivery: apple cultivation is usually the most important stage followed by storage or packaging. However, storage is the main contributor in August, although its importance obviously drops in October and January.

EU2 has a similar distribution of energy use to EU1, although transport to the Regional Distribution Centre (RDC) dominates in most months (except in August, where the increased mass of apples that needs to be produced due to storage loss outweighs transportation costs). The relative importance of cultivation, storage and packaging is identical to EU1.

In the case of NZ, the transportation to Europe always has the largest single contribution to PEU. The importance of apple cultivation is much smaller than in European scenarios (EU1 and EU2) due to the relatively smaller energy intensity (about 2–2.5 times smaller than European or OSH scenarios). Packaging, and in some months (October and January) storage, are more relevant than cultivation.

Finally, apples from other Southern Hemisphere countries consumed in Europe (OSH) follow a similar pattern to NZ apples, as shown in Table A2. Again, transport to Europe is the largest single contributor to PEU, although it is about half the amount found in NZ apples due to the much shorter distance considered (see Table A1). Energy for transportation is equalled by energy use in storage for apples sold in January in Europe. PEU for apple cultivation is higher in the OSH scenario than for NZ apples.

As discussed in Section 1.2, it has been considered that apples imported from the Southern Hemisphere are stored in the Southern Hemisphere until they are transported for retail in Europe. If, on the other hand, the apples were imported and then stored in Europe, the overall energy use would increase because more apples would be transported from the Southern Hemisphere to Europe prior to storage. For instance, the January scenario for apples imported from OSH in June and stored for 7 months in Europe (with a 15% loss) would have a PEU of 5.9 MJ/kg (range 4.6–7.7 MJ/kg) apples in shop, 5% (range: 2.5%–10%) more energy than the scenario presented in Table A2.

Table A1: Supplier-dependent parameters (representative, minimum and maximum values)

	Unit	EU1 (same country)			EU2 (different country)			NZ			Other Southern Hemisphere		
		Rep	MIN	MAX	Rep	MIN	MAX	Rep	MIN	MAX	Rep	MIN	MAX
Apple cultivation ^a	MJ/t	1070	400	2000	1070	400	2000	470	400	700	1070	400	2000
Transport to coldstore, 40 km, < 18 t truck ^b	MJ/t/km	3.47	2.5	4	3.47	2.5	4	3.47	2.5	4	3.47	2.5	4
Initial cooling ^c	MJ/t	86.3	n.c.	n.c.	86.3	n.c.	n.c.	86.3	n.c.	n.c.	86.3	n.c.	n.c.
CA storage 1°C ^c	MJ/t/day	5.4	n.c.	n.c.	5.4	n.c.	n.c.	5.4	n.c.	n.c.	5.4	n.c.	n.c.
Transport to Europe, reefer ^c	MJ/t/km	–	–	–	–	–	–	0.11	n.c.	n.c.	0.11	n.c.	n.c.
distance ^d	km	–	–	–	–	–	–	23000	22000	25000	12000	10000	14000
cooling on board ^c	MJ/t/day	–	–	–	–	–	–	10.8	n.c.	n.c.	10.8	n.c.	n.c.
days on board ^d	days	–	–	–	–	–	–	28	27	30	15	12	17
Road transport to RDC, from port or coldstore in EU, < 40 t refrigerated truck ^e	MJ/t/km	1.2	1	1.4	1.2	1	1.4	1.2	1	1.4	1.2	1	1.4
distance ^f	km	100	60	200	1000	500	2000	250	170	350	250	170	350
Packaging ^c	MJ/t	650	n.c.	n.c.	650	n.c.	n.c.	650	n.c.	n.c.	650	n.c.	n.c.
Transport from RDC to retail < 40 t refrigerated truck ^e	MJ/t/km	1.2	1	1.4	1.2	1	1.4	1.2	1	1.4	1.2	1	1.4
distance ^f	km	150	50	300	150	50	300	150	50	300	150	50	300

Rep: Representative value (see Section 3 for explanation).

n.c.: uncertainty has not been considered for these values, even though they will obviously be variable as well. The reason for not considering a range of values is that no more detailed information was available for these parameters to estimate potential ranges. However, a sensitivity analysis has been performed considering ±40% variation on the reported value (see text in section 4).

CA stands for Controlled Atmosphere

RDC stands for Regional Distribution Centre

^a Data from our own studies [4,7,8,9]

^b Representative value from [5]. Min and Max values derived from our own studies and consultations with industry

^c Data from [5]

^d Representative value for NZ from [5]. Other values derived from typical transportation distances between main supplier and European ports

^e Data from our own studies and consultations with industry

^f Distances estimated from consultations with industry

Potential Effects of Packaging on Primary Energy Use

If retail packaging was included, this could influence the results to a large extent; e.g. a 15g expanded polystyrene tray plus 10 g polyethylene film holding 4 apples (ca. 700 g net weight) 'costs' ca. 3.3 MJ [18] i.e. about 4.7 MJ/kg apples.

Potential Effects of Meal Preparation on Primary Energy Use

Using models from Sonesson et al. [19] baking 1 kg of apples for an apple crumble using an electric oven at 190°C for 40 minutes would use ca. 2 MJ/kg of electricity (i.e. ca. 5MJ of primary energy). The variability in this figure is thus likely to affect the results to a larger extent than other items in the energy bill.

Table A2: Energy use (MJ/kg apples in retail outlet) per different life cycle items in the different seasons in each scenario

Scenario	Seasons	January	April	August	October
	Stages	Median (min–max)	Median (min–max)	Median (min–max)	Median (min–max)
EU1 (European consumption in country of production)	Apple cultivation	1.1 (0.4–2)	1.3 (0.44–2.3)	1.5 (0.49–3)	1.1 (0.4–2)
	Transport to coldstore, 40 km, < 18 t truck	0.13 (0.1–0.16)	0.15 (0.11–0.19)	0.17 (0.12–0.24)	0.13 (0.1–0.16)
	Storage (Initial cooling + CA storage 1°C)	0.57 (0.57–0.57)	0.99 (0.96–1.1)	2 (1.8–2.4)	0.25 (0.25–0.25)
	Transport to Europe, reefer (including cooling on board)	–	–	–	–
	Road transport to RDC, from port or coldstore in EU, < 40 t refrigerated truck	0.14 (0.063–0.27)	0.14 (0.063–0.27)	0.14 (0.063–0.27)	0.14 (0.063–0.27)
	Packaging	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)
	Transport from RDC to retail < 40 t refrigerated truck	0.2 (0.053–0.41)	0.2 (0.053–0.41)	0.2 (0.053–0.41)	0.2 (0.053–0.41)
	Totals	2.8 (2–3.9)	3.4 (2.4–4.6)	4.7 (3.4–6.6)	2.5 (1.6–3.5)
EU2 (European consumption of European apples in different country of production)	Apple cultivation	1.1 (0.4–2)	1.3 (0.44–2.3)	1.5 (0.49–3)	1.1 (0.4–2)
	Transport to coldstore, 40 km, < 18 t truck	0.13 (0.1–0.16)	0.15 (0.11–0.19)	0.17 (0.12–0.24)	0.13 (0.1–0.16)
	Storage (Initial cooling + CA storage 1°C)	0.57 (0.57–0.57)	0.99 (0.96–1.1)	2 (1.8–2.4)	0.25 (0.25–0.25)
	Transport to Europe, reefer (including cooling on board)	–	–	–	–
	Road transport to RDC, from port or coldstore in EU, < 40 t refrigerated truck	1.4 (0.54–2.7)	1.4 (0.54–2.7)	1.4 (0.54–2.7)	1.4 (0.54–2.7)
	Packaging	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)
	Transport from RDC to retail < 40 t refrigerated truck	0.2 (0.052–0.41)	0.2 (0.052–0.41)	0.2 (0.052–0.41)	0.2 (0.052–0.41)
	Totals	4.1 (2.6–6.1)	4.7 (3–6.8)	5.9 (4.1–8.7)	3.8 (2.2–5.8)
NZ (European consumption of apples produced in New Zealand)	Apple cultivation	0.62 (0.45–0.91)	0.51 (0.4–0.7)	0.51 (0.4–0.7)	0.55 (0.42–0.77)
	Transport to coldstore, 40 km, < 18 t truck	0.16 (0.11–0.21)	0.13 (0.1–0.16)	0.13 (0.1–0.16)	0.14 (0.11–0.18)
	Storage (Initial cooling + CA storage 1°C)	1.5 (1.4–1.6)	0.25 (0.25–0.25)	0.41 (0.41–0.41)	0.79 (0.77–0.82)
	Transport to Europe, reefer (including cooling on board)	2.9 (2.7–3.1)	2.9 (2.7–3.1)	2.9 (2.7–3.1)	2.9 (2.7–3.1)
	Road transport to RDC, from port or coldstore in EU, < 40 t refrigerated truck	0.29 (0.17–0.48)	0.29 (0.17–0.48)	0.29 (0.17–0.48)	0.29 (0.17–0.48)
	Packaging	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)
	Transport from RDC to retail < 40 t refrigerated truck	0.2 (0.056–0.41)	0.2 (0.056–0.41)	0.2 (0.056–0.41)	0.2 (0.056–0.41)
	Totals	6.3 (5.7–7)	4.9 (4.5–5.5)	5.1 (4.6–5.6)	5.5 (5.1–6.1)
OSH (European consumption of apples produced in Southern Hemisphere countries other than New Zealand)	Apple cultivation	1.4 (0.47–2.6)	1.1 (0.4–2)	1.1 (0.4–2)	1.2 (0.43–2.2)
	Transport to coldstore, 40 km, <18t truck	0.16 (0.11–0.21)	0.13 (0.1–0.16)	0.13 (0.1–0.16)	0.14 (0.11–0.18)
	Storage (Initial cooling + CA storage 1°C)	1.5 (1.4–1.6)	0.25 (0.25–0.25)	0.41 (0.41–0.41)	0.79 (0.77–0.82)
	Transport to Europe, reefer (including cooling on board)	1.5 (1.2–1.7)	1.5 (1.2–1.7)	1.5 (1.2–1.7)	1.5 (1.2–1.7)
	Road transport to RDC, from port or coldstore in EU, < 40 t refrigerated truck	0.31 (0.18–0.48)	0.31 (0.18–0.48)	0.31 (0.18–0.48)	0.31 (0.18–0.48)
	Packaging	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)	0.65 (0.65–0.65)
	Transport from RDC to retail < 40 t refrigerated truck	0.2 (0.056–0.41)	0.2 (0.056–0.41)	0.2 (0.056–0.41)	0.2 (0.056–0.41)
	Totals	5.6 (4.3–7.3)	4.2 (3.1–5.5)	4.3 (3.3–5.7)	4.8 (3.7–6.3)