Energy Use in the Food Sector:

A data survey

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Abstract

The study presented here is a survey of data for estimating energy requirements in the food sector. It contains a large number of data about the energy required for crop farming, animal husbandry, food processing, storage, transportation and food preparation. The survey is based on published material or information communicated directly to the authors. Recommendations for further data surveys are made.

This database can be used for estimating the energy use for various food items over their life-cycle. The applicability of the database is exemplified by estimating the energy requirements of a hamburger with bread, lettuce, onions, cucumbers and cheese. The possibilities for lowering the energy use of a hamburger are discussed briefly on the basis of the results.

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Contents

1. Introduction

There is an increasing worry about the ecological consequences of consumption and production patterns adopted by the wealthy nations (Loh et al, 1998, Parikh and Painuly, 1994). This worry is well documented in many international declarations and action plans (e.g. United Nations, 1993) where more sustainable patterns of production and consumption are called for.

Food is a basic human need, and therefore it is important to find ways to make food consumption patterns sustainable. Food consumption affects the environment in numerous ways. Throughout the life cycle of food, which includes agricultural production, storage, transportation, processing, preparation and waste disposal, resources are used and emissions are released to the environment (e.g. Andersson, 1998). The whole chain of food production and consumption also uses a lot of energy: 1/5 of the total energy use in Sweden (Uhlin, 1997).

1.1 Why this report?

In the spirit of Agenda 21, numerous efforts have been made to inform consumers about the environmental consequences of consumption choices. Such efforts have resulted in the provision of Green Consumer Guides (e.g. Brower, 1999) or research projects where consumers have been actively involved in striving for more sustainable consumption patterns (e.g. the Perspectief project in the Netherlands). Such studies require large amounts of data often laborious and/or hard to come by.

The idea to produce a survey of data about resource use in the food sector first came to our minds in spring 1999 when attending a workshop on sustainable household consumption in the Netherlands. [1] It became apparent that a new scientific research area was being established: that of household consumption and its related environmental impacts. We heard about several projects related to food consumption, all based on quantitative data from the food sector. Unfortunately, the data used for making these estimations sometimes seemed very hard to come by. In some cases research groups used quantitative estimations made by others without having access to original data sources, and this, of course, makes a scrutiny of results presented difficult.

As both of us have for some time been working with data collection about resource use in the food sector we decided to pool our common knowledge into a report. We thought this useful because:

- A lot of useful data is published in national languages not commonly spoken outside the home country, something that is especially true for the Swedish material.
- A lot of useful data is published in "grey" literature (reports, handbooks, memos) hard to access through conventional literature databases

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[1] The second International Symposium on Sustainable Household Consumption, Household Metabolism: from concept to application. Groningen-Paterswolde, the Netherlands, June 3-4, 1999.

- By compiling several examples of e.g. a crop budget for the same crop one can get a feeling of whether or not existing material indicates large deviations in resource use per unit of product produced. If so, this may be an indication of that further data collection is needed. Special care should be taken when estimating the resource use involving that particular crop.
- By systematically organising data it is possible to see in which areas there is already a lot of information and where there is not.
- By using the compiled data for analysing some food items it is possible to show the extent to which results can vary depending on data divergences. These divergences are an indication of the scope for lowering energy requirements by using resource efficient technologies. They are also an indication of the uncertainties in an analysis.

This report should be seen as a first attempt to present an overview of data sources and data that can be used by those groups or individuals interested in more sustainable patterns of food consumption and production. Hopefully, the future will bring much more complete data surveys where use of e. g. water and materials, not covered here, will be included as will more updated figures for e. g. food processing.

1.2 Data quality

The data presented in this report are of two types:

- Data from published material
- Data that has been communicated directly to us.

We have not systematically controlled data quality in the sense that we did not trace the origin of all data or cross-checked that all secondary data were referred to correctly. We would welcome future data surveys with this ambition.

The general expectation is that processes become more resource efficient with time. Age of data is therefore often a good indicator of how representative figures may be for analysing current conditions. We have given information about data age whenever possible and we have referred to the exact pages in publications so that the data can be accessed quickly.

1.3 The structure of the report

What data is needed to make an estimation of the energy used during the life-cycle of a food item, here exemplified by a hamburger with bread and other ingredients? We have structured our report around this question in an attempt to present the data survey in an instructive and clear way. The analysis of the hamburger is presented in section 2 and Appendix 1. It is followed by an account of the data survey (section 3) that we have organised in a sequence logical for an analysis:

- Recipes, section 3.1 and Appendix 2
- Losses and mass transformation coefficients along the food production chain, section 3.2 and Appendix 3.
- Information about the energy and material requirements of the processes needed for bringing the hamburger to the consumer. That includes data about crop production (section 3.3 and Appendix 4), animal husbandry (section 3.4 and Appendix 5), food

processing (section 3.5 and Appendix 6), storage (section 3.6 and Appendix 7) and locations (section 3.7).
- Complementary information needed for calculating the energy use of a hamburger during its life-cycle. This includes data about energy coefficients (section 3.8 and Appendix 8), energy use for transport (section 3.9 and Appendix 9) and production of farm inputs (section 3.10 and Appendix 10).

Some guidelines for allocation are discussed in section 4. Section 5 lists some major conclusions from the study and section 6 contains a list of references.

2. Mass flows and energy use for a hamburger with bread and other ingredients

The data presented in this report makes it possible to make a rough estimation of the energy use during the life-cycle of a hamburger with bread and other ingredients. Our purpose with this estimation is:

- to see if the data-base presented in sections 3 in this report can be used for quickly making an estimation of energy use over the life-cycle for various foods
- to present two different levels of energy use for food that represent possible choices concerning energy efficiency of appliances and processes during an analysis.

The hamburger ingredients are analysed one. Details about assumptions made are presented in Appendix 1, Mass flows and energy use of a hamburger and other ingredients. The energy estimates include conversion losses as well as production and delivery energy. The recipe, which is the starting point of the analysis, is presented in Table 1.

Table 1: Recipe for a hamburger with bread and other ingredients (Mac Donalds Sweden 1999, personal communication about a BigMac)

Ingredients	kg/hamburger
Bread	0,0740
Hamburger	0,0900
Dressing	0,0200
Lettuce	0,0280
Onions (freeze dried)	0,0017
Cucumber (pickled)	0,0074
Cheese	0,0145

2.1 Bread

The mass flows for bread is presented in Table 2 and the energy use in Table 3. In each calculation of the energy requirements we estimated a lowest and highest value so as to show the range of the variations in the data.

We assume that the bread is frozen and put in storage for some time before preparation of the hamburger. We do not estimate mass flows for ingredients other than wheat flour. From the recipe of bread presented in Table 1, Appendix 2, it is obvious that wheat flour and water are the main ingredients in bread while margarine, yeast, sugar and salt are minor inputs.

Table 2: Mass flows of hamburger bread

	kg/hamburger
kg bread	0.074
kg bread to restaurant	0.078
kg bread to storage facility	0.078
kg bread baked	0.097
kg flour needed	0.067
kg wheat milled	0.083
kg wheat cultivated	0.083

Table 3: Energy use for hamburger bread (MJ per 74 grams bread)

	Low, MJ	High, MJ
Crop production incl. drying	0.17	0.24
Milling	0.03	0.39
Baking	0.45	1.0
Storage	0.31	1.6
Transportation	0.07	0.09
Total	**0.96**	**3.2**

The energy use per kg of hamburger bread becomes 13-44 MJ per kg in our example. Baking and storage are the most energy consuming stages and transportation the least energy consuming one. Assumptions about resource use during crop production, storage time and transportation distances are equal in both examples.

2.2Hamburger

The estimation of the mass flows for the hamburger is more complex than for bread because it involves accounting for fodder needs of cattle. The mass flows are presented in Table 4 -5 and the energy use in Table 6.

Table 4: Mass flows of a hamburger

	kg/hamburger
kg meat	0.090
kg meat to frying table	0.093
kg meat to restaurant	0.11
kg meat to storage facility	0.11
kg meat to cutter	0.14
kg animal to slaughter house	0.23
kg of feed consumed	1.45

Table 5: Feed requirements for a hamburger (Appendix 5, Table 7a)

Feed composition	kg/hamburger
Cereals	0.68
Protein fodder	0.043
Coarse fodder, DM	0.72
Pasture on arable land, DM	0
Pasture, cutover, DM	0

In our example, we assumed that the meat came from a spring born calf that eats 2'728 kg of feed before attaining a carcass weight of 265 kg. The feed consumption per kg live weight is 6.4 kg with a dressing yield of 62 %. The feed is supposed to be composed of barley (cereals), fodder peas (protein fodder) and hey (coarse fodder). We assume that the amount of feed consumed is equal to the amount of barley, peas and hey produced not considering losses during feed preparation or farm losses.

Table 6: Energy use for a hamburger (MJ per 90 grams meat)

	Low, MJ	High, MJ
Crop production, drying, fodder production	3.5	5.0
Stable, slaughtering, cutting	0.23	1.4
Grinding, freezing	0.12	0.16
Storage	0.45	2.3
Frying	0.79	1.0
Transportation	0.44	0.59
Total	**5.6**	**10**

The energy use per kg of hamburger becomes 62-116 MJ per kg in our example. Crop production, drying and fodder production are the most energy demanding stages followed by storage and frying. We have assumed that the hamburger is frozen after processing. Assumptions about resource use during crop production, storage time and transportation distances are equal in both examples.

2.3 Dressing

As we did not have any recipe for dressing, we omitted this ingredient from the analysis.

2.4 Lettuce

The mass flows for lettuce (Table 7) are fairly easy to analyse as this ingredient is of vegetable origin and has not been processed.

Table 7: Mass flows for lettuce

	kg/hamburger
kg lettuce	0.028
kg lettuce to restaurant	0.039
kg lettuce harvested	0.039

The energy use for lettuce (Table 8) show high variations due to the cultivation methods assumed: open ground or in greenhouse. The energy use per kg of lettuce varies between 3.4-160 MJ per kg. For lettuce produced in greenhouse, it is the crop production stage that is the most energy demanding. Assumptions about storage time and transportation distance are the same in both examples.

Table 8: Energy use for lettuce (MJ per 28 grams lettuce)

	Low, MJ	High, MJ
Crop production	0.04	4.27
Storage	0.02	0.05
Transportation	0.04	0.04
Total	**0.09**	**4.36**

2.5 Onions (freeze-dried)

The mass flows for freeze-dried onions (Table 9) shows that it takes about 12 kg of fresh onions to obtain one kg of freeze-fried onions when losses during storage and processing etc. are accounted for.

Table 9: Mass flows for freeze-dried onions

	kg/hamburger
kg onions	0.0017
kg onions to restaurant	0.0021
kg onions to storage facility	0.0021
kg onions entering processing in freeze-dry plant	0.017
kg onions delivered to freeze-dry plant	0.020
kg onions entering long-term storage	0.021
kg onions harvested	0.021

The energy use for freeze-drying onions has been estimated from data about fabrication of potato flakes and freezing of foods in general. More accurate data on the freeze-drying process would be needed for further analysis, especially since freeze-drying seem to be the most energy consuming stage in the life-cycle of the onions studied. The energy use per kg of freeze-dried onions varies from 32-62 MJ in our example. Assumptions about crop budget, storage time and transportation distances were equal in both energy estimates. Energy use for storage after processing (in room temperature) has not been estimated (Table 10).

Table 10: Energy use of freeze-dried onions (MJ per 1.7 grams freeze-dried onions)

	Low, MJ	High, MJ
crop production	0.012	0.015
freeze-drying	0.041	0.073
storage	0.0039	0.0093
transportation	0.0085	0.0109
Total	**0.057**	**0.12**

2.6 Cucumber, pickled

The mass flows for pickled cucumbers (Table 11) shows that about 2.5 kg of cucumbers are harvested for every kg pickled cucumber in a hamburger. Data for canning of tomatoes were used for the processing estimate and losses during storage of cucumbers prior to processing were assumed to be zero.

Table 11: Mass flows for pickled cucumbers

kg cucumber/Big Mac	0.0074
Kg cucumber to restaurant	0.010
kg cucumber to storage facility	0.010
kg cucumber entering processing in canning plant	0.016
kg cucumber delivered to canning plant	0.019
Kg cucumber harvested	0.019

The energy use for pickled cucumber varies from 6.2-7.6 MJ per kg in our examples (Table 12) where assumptions about crop budget, storage time and transportation distances are the same. A storage time of 30 days prior to processing is assumed and data on energy use for pickling is taken from estimates about canning of fruits and vegetables. As with the onion example, it is the processing stage that is the most energy demanding. This is probably a characteristic feature of many processed vegetable products. We have assumed that the cucumbers were cultivated on the open ground.

Table 12: Energy use of pickled cucumber (MJ per 7.4 grams pickled cucumbers)

	Low, MJ	High, MJ
crop production	0.0074	0.0097
storage	0.0008	0.0074
pickling	0.02	0.032
transportation	0.014	0.0072
Total	0.046	0.056

2.7 Cheese

As with the hamburger, analysing mass flows for cheese includes accounting for fodder needs of dairy cows. The mass flows for cheese (Table 13-14) shows that about 12 kg of milk are needed for 1 kg of cheese in a hamburger. In our example we assumed that milk came from a cow that eat 5’820 kg of feed while milking 7’300 kg of milk during one year. The feed is supposed to be composed of barley (cereals), fodder peas (protein fodder) and hey (coarse fodder and pasture). We assume that the amount of feed consumed is equal to the amount of barley, peas and hey produced not considering losses during feed preparation or farm losses. No allocation was made to the meat of the cow's calf.

Table 13: Mass flows for cheese

	kg/hamburger
kg cheese	0.015
kg cheese to restaurant	0.017
kg cheese to storage facility	0.017
kg milk to dairy plant	0.18
kg milk milked from cow	0.18
kg feed consumed	0.14

Table 14: Feed requirements for cheese (Appendix 5, Table 8a)

feed composition	**kg/hamburger**
Cereals	0.037
Protein fodder	0.015
Coarse fodder	0.065
Pasture	0.022
Minerals	0.0005

The energy use per kg of cheese becomes 38-62 MJ per kg in our examples. Crop and fodder production, milking and making cheese are the most energy demanding stages. Long-term storage was not supposed to consume energy, as cheese is commonly stored in caves that naturally hold suitable temperatures. Storage in a refrigerator during 15 days is included and the transportation distances are the same in both examples (Table 15).

Table 15: Energy use for cheese (MJ per 15 grams cheese)

	Low, MJ	**High, MJ**
Crop production, drying, fodder production	0.26	0.37
Milking, making cheese	0.16	0.32
Storage	0.01	0.07
Transportation	0.11	0.15
Total	**0.54**	**0.90**

2.8 Total energy use for a hamburger

When we summarise the analyses for the various ingredients in a hamburger, the resulting energy use varies between 7.3-20 MJ (Figure 1). It is the hamburger itself that requires the most energy followed by lettuce if this crop is cultivated in a greenhouse. The energy use for the ingredients freeze-dried onions and pickled cucumber are minor when compared to the total; together they represent only about 1 %.

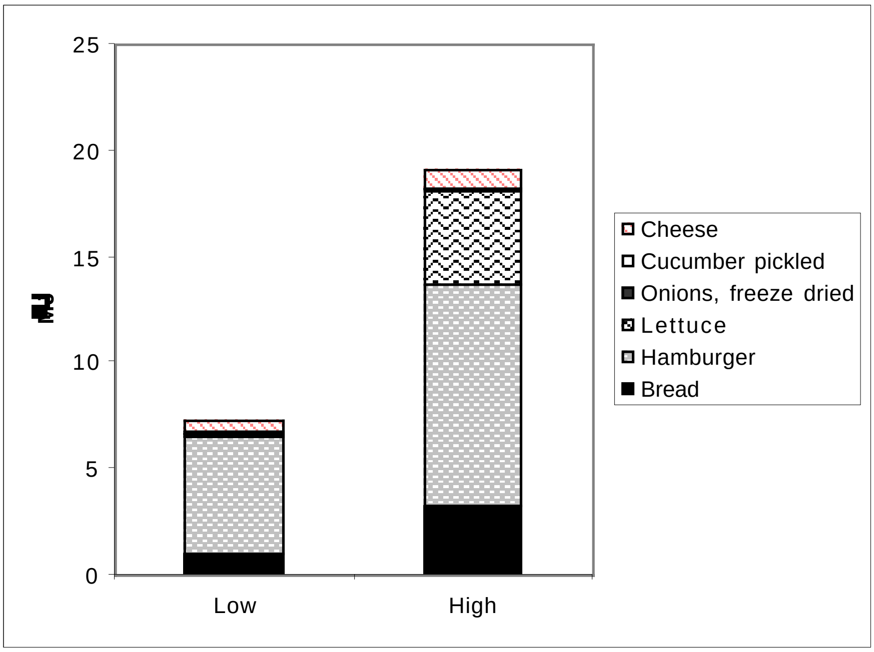

Figure 1: Energy use for a hamburger (MJ per hamburger with bread, lettuce, cucumbers, onions and cheese).

The variation in energy use is an indicator of the potential for lowering energy use by using today's most efficient technology in lorries, refrigerators and industrial processes. There are, however, several other options for obtaining even lower energy values. Some of these are:

- A higher utilisation level of animal body parts (less body parts for other uses than human consumption)
- Burgers made of vegetables, chicken or fish
- No lettuce from greenhouse
- Shorter storage time for frozen ingredients such as bread and meat

3. The Data Survey

3.1 Recipes

Obtaining recipes is a crucial step for estimating resource use from food products and most often the starting point of an investigation. Recipes are descriptions of the ingredients necessary for preparing food products composed of several food items. We have not made any attempt to make an extensive account of recipes here, as they can vary from product to product. Recipes are relatively easily available from e.g. food packaging, cookbooks or food industries information desks. Some few examples of recipes are given in Appendix 2 and the recipe for the hamburger with bread and other ingredients was presented in Table 1.

3.2 Loss and mass transformation coefficients

Loss and mass transformation coefficients give information about the amounts of products needed to obtain one food item out of another. Examples of mass transformations are the production of flour out of grain or the production of meat or eggs through the metabolism of grain or other fodder by animals. There are numerous types of transformations to be considered for supplying consumers with a Western type of diet. Several of these have multiple outputs, exemplified by oily crops, such as rape seed being transformed into oil and meal or fodder being transformed into milk and meat. Further, information about the magnitude of food losses are necessary inputs in a mass balance. Food losses occur at all steps when handling or storing food: quality deterioration of fruit and vegetables during storage is one example and losses of food during processing because food cling to equipment is another.

In Appendix 3, Table 1-14, there are losses and mass transformation coefficients for:

- **Food processing** (Table 1a-c)
- **Food preparation** (Table 2)
- **Food losses** (Table 3)
- **Feed conversion** (Tables 4-11)
- **Dressing shares** (Table 12-13)
- **Animal body parts in percentage of live weight** (Table 14)

Examples from **food processing** are the transformation of milk into cheese, which requires about 10 litres milk/kg cheese,or the transformation of grain into flour, which requires 1.3 kg grain/kg flour. Food processing is related to the industry while food preparation happens mostly in households or restaurants.

Mass transformation coefficients for **food preparation** have information about weight losses of food during cooking or frying, in the household or elsewhere. Examples are that it requires 1.28 units of raw chicken to obtain one unit of fried chicken or that it takes 1.25 units of potatoes to obtain one unit of boiled and peeled potatoes.

Coefficients for **food losses** are rather scarce and needs to be complemented. On a global basis, one quarter of the food entering the institutional and household distribution system is lost. Levels of waste are closely correlated with levels of income, with little end use food waste at low levels of income, but with 30-60 % of food requirements lost in high income countries (Bender, 1994). Examples of waste levels from Table 3, Appendix 3, are that 1.2 units of meat is required for every unit of meat eaten and that for every unit of potatoes "surviving" long-term storage, 1.22 units of potatoes have entered the storage facility.

Transformation coefficients for **feed conversion** (or feed consumption) is given per animal for animals mostly used for breeding or feeding and per live weight or carcass weight for animals normally slaughtered. The carcass weight of an animal is obtained by multiplying the live weight with the dressing share [2] that varies from animal to animal and with feeding practices. For example, the dressing share of cattle vary with feed composition as grazing cattle have a heavier stomach content than cattle fed with grain do.

Feed conversion efficiencies vary: for egg production, between 2.2 and 2.7 kg of feed per kg of egg may be needed. Generally, fish and broilers are the most efficient feed converters with 1.1-2.6 kg of feed per kg of carcass.[3] Sheep are much less efficient with 12 kg of feed per kg of carcass. Feed composition for different kinds of animals vary substantially as will be shown in section 3.4, Animal Husbandry and Appendix 5. Table 13 in Appendix 5 have two

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[2] A definition of dressing percentage or dressing share is "a measure of the percentage yield from slaughtered animals derived by comparing the weight of a chilled carcass with its live weight" (Lipton, 1995).

4. For fish the data for this estimation is taken from Table 11, 1 kg of feed per kg of fish and from Table 13, dressing share for salmon of 0.91 (1/0.91). For broilers the data for the estimation is taken from Table 5, 4.4 kg of feed for a bird with a live weight of 2.3 kg and from Table 12, dressing share of a broiler 0.73 (4.4/2.3/0.73).

examples of **inputs in aquaculture** where the feed conversion rate is much less efficient than the figures presented in Table 11, Appendix 3. Age of data may be one explanation for these differences.

Ways of estimating the **dressing share** also varies from country to country: the inclusion or exclusion of fat in the abdomen is one reason for these variations. Dressing shares for broilers and pigs are higher than for cattle and sheep. One unit of a broiler gives 0.7 unit of carcass while one unit of cattle gives 0.5-0.6 unit of carcass. Carcass weight is not always the same as "eatable" meat. When broilers are sold whole, carcass weight and "eatable" amount of meat is equal with no regards for household waste from skin and bones. For pork and beef, carcass weight is not the same as eatable meat because blood and inedible parts are removed from the carcass and never enter the dinner table (at least in Sweden). The taste and culture in human societies vary however, with consequences for the demand of animal body parts. In Sweden, intestines are not much in demand and sometimes exported to Africa where they are more popular. Dog food is another destiny for unpopular animal body parts. When performing an environmental analysis of food, the specific situation in the country or culture studied should be considered for determining how resource use during slaughter and the other meat processing steps should be allocated.

The Table about **Animal body parts in percentage of live weight** (Table 14, Appendix 3) gives some basic information about the partitioning of various body parts from some common livestock. This information can be used as a starting point when investigating the various allocation options during animal husbandry and slaughtering.

Additional data for analysing mass flows can be found under section 3.3, Crop production and section 3.4, Animal husbandry with aquaculture. From the former section, mass flows of agricultural inputs such as fertilisers can be analysed. From the latter section mass flows of specific fodder components can be established.

3.3 Crop production

Resources such as diesel, gasoline, fertilisers, pesticides and seeds are commonly needed during crop production. Appendix 4 contains data about resource use and the respective yield of a large number of crops. [4] The data is organised as follows:

- **Grains and legumes**, with examples from 12 crops of major importance for world food supply. For most of these crops, there are examples from several countries in the North. Data for the following crops can be found: barley, corn, dry beans and peas, oat, peanuts, rape seed, rice, rye, sorghum, soy beans, sunflower seed and wheat.
- **Fruit and vegetables** with examples from 24 of the major vegetables, with several examples both from cultivation on the open ground and in greenhouses. For many of these crops there are examples from several countries. Data for the following crops can be found: apples, bananas, beans green, broccoli, cabbage Chinese, cabbage white, carrots, cucumbers, cherries, grapes, lettuce, onions, olives, oranges, palm fruits, parsley, peas green, potatoes, strawberries, sweet pepper, red beets, sugar beets, squash and tomatoes.
- **Forage crops etc**. with examples from fodder beets, hey, corn, silage and pasture.

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[4] Energy use is given as process energy. "Process energy is the energy input required and consumed by the considered process to operate within the process phase, excluding production and delivery energy" (Audesley, 1997, p. 28).

With the help of this data it is possible to get a rough estimation of the variations in inputs per unit of output for several crops. Soil and climate differ from country to country, as do cultivation methods. Therefore it is natural to find variations in data for crop production. Some examples of this are given below (Table 16):

Table 16: Litres of diesel per kg of crop during crop production

Litre diesel per kg crop	Average	Median	Min	Max
Wheat (9 observations)	0.018	0.017	0.013	0.034
Rape seed (10 observations)	0.043	0.038	0.027	0.063
Potatoes (9 observations)	0.0090	0.0093	0.0047	0.014

There are nine observations for wheat where diesel is the only energy input during crop production (Table 1.11, Appendix 4). The average, median, minimum and maximum values for diesel use per unit of wheat harvested, given in Table 16, shows that the maximum value is almost three times as big as the minimum value. The highest value for wheat was found for an organically produced crop (Switzerland) and the lowest for conventionally produced winter wheat (Sweden). This difference is mainly due to the lower yield of organic production.

The 10 observations for rape-seed (Table 1.6, Appendix 4) shows that the average, median, minimum and maximum values for diesel use per unit of rape-seed harvested (Table 16) are more than twice as high as for wheat. This is mainly due to lower yields for rape-seeds. Both the highest and lowest values in Table 16 were found for conventionally produced winter rape-seeds that were grown in Sweden.

The nine observations for potatoes (Table 2.20, Appendix 4) shows that the average, median, minimum and maximum values for diesel use per unit of potato harvested (Table 16) are at least half those of wheat. This despite that diesel use per ha during potato cultivation is higher but high yields counteract this. There are potato cultivation systems where the diesel use per unit of harvest is as high as for wheat as well as systems where the diesel consumption is as low as 0.005 litres/kg of potato.

These examples show that estimations about resource inputs in agriculture are subject to high variations. Differences in climates and soils as well as cultivation methods influence the resource use. However, the data collected here don't allow any general comments about the magnitude of this influence.

Resource use for cultivation on the open ground or in greenhouses differ substantially as can be seen from e.g. Table 2.8 and 2.9, Cucumbers, Appendix 4. In Table 17, the inputs of fuels in the two cultivation systems are compared per unit of output. The result shows that cucumbers in greenhouses require more than 100 times the fuel needed for cultivation on the open ground. Comparisons with similar results can be made for lettuce (Table 2.12 and 2.13, Appendix 4), strawberries (Table 2.21-2.22, Appendix 4) and tomatoes (Table 2.27-2.28, Appendix 4)

Table 17: Use of fuel for cultivation of cucumbers in the open and in greenhouses.

	Cucumbers, open ground	Cucumbers, greenhouse
Litres of fuel per m2	0.034	48
Harvest kg per m2	4.5	55
Litres of fuel per kg of crop	0.0076	0.87

Most fruits are produced from plants with a long lifetime (trees) and usually these crops have to be maintained and cared for during several years before production on-set. Resource inputs during those unproductive years should, ideally, be allocated to the production period of the tree. However, data about resource inputs during establishment are not always available. In Table 2.1, Appendix 4, there are three observations of resource inputs during the lifetime of an apple orchard and seven observations with resource inputs during one productive year only. When we examined the resulting levels of resource inputs per kg of output, we found no systematic differences between these two kinds of observations, however. This indicates that finding data about resource inputs during the establishment phase of fruit trees may not be important. However, this conclusion may not be valid if lifetime of fruit trees is shorter than in our examples.

It is imperative that more data on resource use during crop production becomes available so as to better understand the magnitude of uncertainties in estimates of resource use for various foods.

3.4 Animal Husbandry (with some data on aquaculture and fisheries)

Feed and water is given to animals and resources such as energy and materials are used for providing them with a suitable climate and for giving them the necessary care. Resources are also used for slaughtering, fodder preparation, fishing and aquaculture. In Appendix 5 the data is organised as follows: [5]

- **energy use for fodder production** (Table 1-2)
- **feeding plans for various animals** (Tables 3-9) with feeding plans for laying hens, broilers, pigs (two types), sheep, bulls (five types), steers, fattening bull, milking cows (six types) and heifers (six types).
- **energy use in animal shelters** (Table 10)
- **energy use for slaughtering** (Table 11a-d)
- **energy use for fishing** (Table 12)
- **resource use in aquaculture** (Table 13)

In Table 1, Appendix 5, figures on **energy use for fodder production** show a span of 0.26-0.40 MJ per kg output for fodder ready for consumption. Two figures for drying of whey, a by-product from cheese production commonly used as fodder, show relatively large energy requirements due to the high water content in the fresh whey. Table 2, Appendix 5 contains an estimation of the energy required to produce fishmeal, given as the energy used per kg of input (1.09 MJ diesel). World production of fishmeal were 6’293’000 tonnes in 1990 and during the same year the amounts of landed fish used for other purposes than human consumption was 27’034’000 tonnes (Tacon, 1993, p. 50). This puts the amount of fish needed to produce one unit of fishmeal to 4.3. According to a Swedish fishmeal factory, 5 kg

[5] Energy use is given as process energy.

of fish is required for every kg of fishmeal (Västkustfisk SVC AB, pers. comm., -00). The diesel use per kg of fishmeal may be 4.7-5.5 MJ.

Table 3-5, Appendix 5 has information about the **feeding plans for hens, broilers and pigs**, Since all these animals are monogastric, their feeding plan is composed of cereals and protein rich fodder from e.g. beans, peas or fishmeal. In Table 6-7, Appendix 5, feeding plans are shown for the ruminants' sheep and cattle. Fodder from grass etc. is a dominant ingredient in the feeding plan for these animals, but there are some exceptions. The feeding plan for a fattening bull (Table 7f, Appendix 5) shows that cereals constitute 66 % of the total feed with coarse fodder accounting only for 7 %. This makeup of feeding plan is quite similar to those for broilers and pigs. An intensive feeding plan for a bull in Switzerland however consists of 70% of silage; while fatstock fodder, a protein-rich fodder mixture, is only 25 % (Table 7g, Appendix 5). On the other hand, the feeding plan for sheep is almost entirely composed of coarse fodder and pasture, with cereals only 10% of the total.

In Tables 8 a-f, Appendix 5, there is information about **feeding plans for milking cows** in Sweden and Switzerland. Cereals constitute 22-28 % of the total in the Swedish examples but a minor share in the Swiss feeding plans where grass and silage dominates. Milk yield is also different with lower yields in the Swiss examples. The Swiss and Swedish cases are examples of systems with different intensities.

Tables 9a-f, Appendix 5, show **feeding plans for heifers** in Sweden and Switzerland. The dominating ingredients are generally coarse fodder and pasture. Heifers give birth to their first calf at the age of 24 to 30 months or when they weigh around 500 kg (live weight). In intensive production systems a milking cow may be kept for 2.5 years before being slaughtered and in less intensive the production time is about 5 years. When performing an environmental analysis, fodder requirements for heifers need to be divided by milk produced, the meat obtained and calves born. However, heifers may also be used as suckling cows or as meat. The fate of heifers is important for knowing how fodder requirements for heifers should be allocated in an analysis (se further section 4 for a discussion about allocation).

Data on **energy use in shelters** are shown in Table 10, Appendix 5. This table lacks data about energy use for shelters with bulls, steers and broilers. The energy use for shelters with pigs (two figures) deviate: from 0.41–1.8 MJ electricity per kg carcass produced. [6] It is not known whether or not such variations are common. The reported electricity use for milking and cooling equipment (four estimations) indicates a possible use of 0.2-0.7 MJ per kg of milk. [7] Electricity use for egg production range from 0.72 -1.6 MJ per kg egg.

An energy-consuming phase during **slaughtering** is cooling the carcasses from +37° C to +4° C. We found some figures relevant for slaughtering of cattle, baconers and poultry, shown in Tables 11a-d, Appendix 5. The two observations of energy use for slaughtering of cattle vary from 0.7 -3 MJ per kg carcass. [8]

Efficiency of **energy use for fishing** in the sea varies from 3.4 -13 kg of fish caught per litre of fuel spent (Table 12, Appendix 5). Compared to the efficiency during farm production

[6] Assuming that the baconer weighs 100 kg when slaughtered and that the dressing yield is 0.71 (Table 12, Appendix 3)

[7] Assuming a milk yield of 7000 kg per year for estimations expressed in MJ per cow, year.

[8] Assuming a dressing share of 0.60 for the slaughtering of cattle reported in Heiss (Table 11c, Appendix 5).

fishing appears less efficient with 0.077-0.29 litres of fuel used per kg of fish caught. However, energy for producing inputs such as fertilisers during crop production is not accounted for in that comparison.

Table 13, Appendix 5, has two examples of **inputs in aquaculture**. It is worth noting that the efficiency of feed conversion rate in these examples – 2.1-2.8 kg of feed per kg of fish – is much less efficient than the figures presented in Table 11, Appendix 3. Age of data may be one explanation for these differences.

3.5 Food Processing and Food Preparation

Food processing and preparation requires resources such as energy, water and materials. Appendix 6 has data on energy use for various types of food processing and preparation organised as follows: [9]

1. Food processing

- **Baby food** (Table 1.1)
- **Bread etc.** (Table 1.2)
- **Breakfast cereals** (Table 1.3)
- **Canning etc.** (Table 1.4)
- **Chips** (Table 1.5)
- **Chocolate** (Table 1.6)
- **Coffee** (Table 1.7)
- **Dairy products** (Table 1.8)
- **Drying, energy per unit of water evaporated** (Table 1.9)
- **Drying, energy per unit of dry crop** (Table 1.10)
- **Freezing and cooling** (Table 1.11)
- **Ice cream** (Table 1.12)
- **Juice** (Table 1.13)
- **Meat** (Table 1.14)
- **Milling and polishing** (Table 1.15)
- **Oil extraction and refining** (Table 1.16)
- **Pasta** (Table 1.17)
- **Peeling** (Table 1.18)
- **Soft drinks and alcohol** (Table 1.19)
- **Sugar and Candy** (Table 1.20)

2. Food preparation

- **Food preparation in households** (Table 2.1)
- **Food preparation in restaurants and industries** (Table 2.2)
- **Food preparation: theoretical values based on producer information** (Table 2.3)

The rather large number of observations about energy use for **bread making** (31) give possibilities for discussing variations in energy inputs for this process. There are eight observations of bread making where the only reported energy input is electricity. Energy use in these examples varies between 1.53-4.56 MJ per kg of bread. Two observations of energy use for baking bake-off baguettes at a retailer show energy uses between 1.22-1.87 MJ per kg of bread. To obtain the complete picture of energy use for baking, figures on energy use for pre-baking those products must also be added, but no such data are presented here. As bake-

[9] Energy use is given as process energy.

off products are increasingly becoming popular, collecting such figures should be a priority in further comparative studies of bread supply systems. A single figure for knäcke-bread shows high energy requirements with 15 MJ electricity per kg of bread produced. Further data collection could determine whether or not this level of energy use is representative.

The figures about energy use for **breakfast cereals** vary largely with figures from Pimentel (1996, reference from 1977) adding up to 66 MJ per kg cereal and figures from Singh (1986) of 19 MJ per kg output. It seems necessary to collect more recent data for these processes. Figures about energy use for producing breakfast cereals are expected to vary with a higher energy use for baked products than for those that are just mixed from inputs such as dry fruit and cereal flakes.

According to Table 1.4, Appendix 6, **canning** of fruit and vegetables (three observations) requires between 2.1- 3.8 MJ per kg output and canning of meat (three observations) between 5.2 - 25 MJ per kg output.

Three observations on energy use for **chips** fabrication (Table 1.5, Appendix 6) show little variation with 11-15 MJ per kg output. All figures are of recent origin. A recent figure on energy use from a Swedish plant for **chocolate** production is that 8.6 MJ are used per kg of chocolate bar (Table 1.6, Appendix 6). One observation from fabrication of instant **coffee** is that 50 MJ are needed per kg of coffee (Table 1.7, Appendix 6). Energy use for fabrication of chocolate and coffee should be further investigated for a more reliable data material.

Dairy products seem, together with bread, to be among the most investigated products (Table 1.8, Appendix 6). For milk, there are seven observations where electricity is the only source of energy input during milk processing and the use varies from 0.50-2.6 MJ per kg of milk produced.

Drying is also a process for which there are relatively many observations. The theoretical value for evaporating one kg of water is 2.60 MJ according to Pimentel (1996) who also writes that the real energy use is 2-6 times higher than that, or 5.2-15.6 MJ. This statement can be compared to the other data reported on energy use per kg of water evaporated in Table 1.9, Appendix 6. From these data, it seems that the real energy use is 2-3 times the theoretical value proposed by Pimentel. The energy use per kg of dry crop (Table 1.10, Appendix 6) depends, of course, on the water content before and after drying. One example is 6.4 MJ per kg of output for drying beet pulp from 80 % to 10 % moisture content. Another example is 0.47 MJ per kg of output for drying soybeans from 17 % to 11 % moisture content. Five observations of manufacturing of potato flakes and granules tell that 15-42 MJ per kg of output may be used for these processes. For every kg of potato flakes, 5.3 kg of potatoes are needed. [10] Potatoes usually contain 0.75-0.78 kg of water per kg and dried mashed potatoes about 0.07 kg of water per kg. As 3.6-3.8 kg of water has to be evaporated for every kg of dry potatoes produced, energy use for drying potatoes only may be in the order 19-20 MJ per kg potato flakes. [11]

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[10] Information from food packaging in Sweden - 00: one kg of potato powder contains 860 grams of dried and mashed potatoes. 4.6 kg of potatoes may be needed for producing that amount (Appendix 3, Table 1b).

[11] Assuming two times the theoretical energy value for evaporation of water: 2*2.60 MJ/kg of water*kg of water evaporated. Water evaporated: 5.3 kg of potatoes*0.68-0.71 kg of water per kg.

Energy for **freezing** (Table 1.11, Appendix 6) are in the order of 0.3 MJ electricity per kg of product frozen (two observations) while one observation from Pimentel (1996) gives a figure of 7.6 MJ per kg of output. **Ice cream** production (Table 1.12, Appendix 6) with two observations requires 2.2-3.7 MJ per kg output.

Two observations of energy juice for **juice** fabrication (Table 1.13, Appendix 6) give an energy use of 1.15 MJ per kg output for juice made from concentrate and 4.6 MJ per kg of output for juice made from fresh citrus fruits. Four observations of energy use for fabrication of **sausages** range from 3.9-36 MJ per kg output because degree of processing for sausages vary (Table 1.14, Appendix 6).

Milling is yet another process with relatively many observations (Table 1.15, Appendix 6). Electricity use is between 0.32-2.58 MJ per kg of wheat flour according to 12 observations where electricity is the only energy use recorded. Energy use for **oil extraction** (Table 1.16, Appendix 6) recorded as energy per kg input is in the order of 0.28-1.5 MJ. Generally, two products are obtained during oil extraction, oil and meal, and various allocation procedures can be used to partition the energy use between those two outputs.

Pasta fabrication requires about 0.8-2.4 MJ per kg output (Table 1.17, Appendix 6) and **drinks** between 2.4-6 MJ per kg output (Table 1.19, Appendix 6). Reported energy use for **sugar extraction** (six observations) show a range of 2.3 - 26 MJ per kg output while fabrication of **candy** (Table 1.20, Appendix 6) may require around 6 MJ per kg output.

There are several observations of energy use for **food preparation in households** (Table 2.1, Appendix 6) where the level of energy use is 3-5 MJ per kg of output. Much lower values are found for food prepared in microwave oven (four observations) where energy use per kg of output is lower than 1 MJ. Data on energy use for **food preparation in restaurants and industries** (Table 2.2, Appendix 6) show similar levels of energy use when similar food is prepared.

In Table 2.3, Appendix 6, where **energy use for food preparation is given as theoretical values** for various appliances, it is possible to distinguish some basic characteristics about equipment. Ovens, gas or electrical, are more energy consuming than plates on stoves and much more energy consuming than microwave ovens. Wood stoves are the most energy consuming appliances described in Table 2.3, Appendix 6, but rarely used for food preparation in the North.

In conclusion, data about energy use for food processing show large variations both in terms of energy used for different products and in terms of energy used for fabrication of similar products. Some processes, such as bread baking, milk processing, milling and oil extraction are relatively well documented here while data for other processes, such as wine making, are missing. A more complete account of the various steps involved in food processing would be valuable to get better estimations of the energy use.

3.6 Storage

Energy is used for keeping food at a desirable temperature during storage. Appendix 7 has data on energy use for cold storage and storage in room temperature organised as follows: [12]

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[12] Energy use is given as process energy.

- **Cold storage** with energy requirements of refrigerator and freezers in households, restaurants and industries (Tables 1.1-1.4).
- **Storage in room temperature** with some energy use relevant for households, restaurants and industries (Tables 2.1-2.2).

Table 1.1-1.2, Appendix 7, gives some examples of energy use for storage in refrigerators and freezers in households. There are two types of sources: estimates from different studies and producer information. Producer information gives mostly theoretical values about energy requirements, whereas studies try to find out the real requirements. However, such studies are often based on producer information with assumptions about e.g. room temperature or load of food.

Producer information tells e.g. that a ten-year old refrigerator uses 2.7 times as much energy per litre usable volume as a new A-class one. [13] In an energy analysis of food it is therefore important to examine the assumption made about equipment during storage. Further, it is important to examine assumption about levels of utilisation as they can have decisive influence on results. One example is the energy use for a 10 year old freezer, 0.029 MJ per litre net volume, day which with only 50 % utilisation becomes 0.058 MJ per litre, day. Assuming a storage time of 90 days, energy use for storage in the household becomes 5.2 MJ per litre food. This level of energy use is comparable to those for juice or candy fabrication (Appendix 6, Tables 1.13 and 1.20). If, on the other hand, energy use during storage is based on assumptions about a new A-class freezer (0.012 MJ per litre net volume, day) with a 90 % utilisation, energy use during 90 days is only 1.2 MJ per litre. This is less than a fourth of the energy used in the first example.

Energy use for storage in refrigerators in restaurants, industries etc. (Tables 1.3-1.4, Appendix 7) has been estimated to 0.0025-0.082 MJ electricity per litre net volume, day. The age and size of appliances explains such variations as well as the kinds of products stored. Long-term cold storage of apples may consume between 0.0017-0.0009 MJ electricity per kg, day. This low level of energy consumption means that even if apples are stored during one year, energy use does not exceed 0.7 MJ.

Energy consumption in cold racks and other equipment where products are exposed to consumers is much higher than for any other facility investigated. Cold racks at Swedish retailers may use 0.12 MJ per litre usable volume, day and if assuming a utilisation rate of 75 % and a storage time of one week the energy use exceed 1 MJ per litre. That is more than for the long-term storage of apples during one year.

Energy use for storage in freezers varies with freezer size as demonstrated by BELF (1983). Energy use per litre net volume, day can be 0.0010 MJ when food is stored in rooms of 10’000 m^3 while it can be 0.015 MJ when food is stored in rooms of $10m^3$. The difference is a factor 15.

Energy use for storage in room temperature is naturally lower than for cold storage as no extra energy is used for cooling already heated premises. Based on estimates of energy use for heating Swedish average houses, the energy use for storage of products in room temperature can be estimated to 0.00064 MJ per litre and day. Storing a litre of flour at home for a year

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[13] There is a labelling system for energy efficiency of household appliances within the European Union. The A-label is for the most energy efficient appliances, while B,C and D labels indicate energy efficiency in descending order.

use 0.23 MJ if only energy for heating is accounted for. It can be discussed whether or not household storage of food in room temperature should be included in an analysis. Food occupies a minor share of household space, at least in today's households.

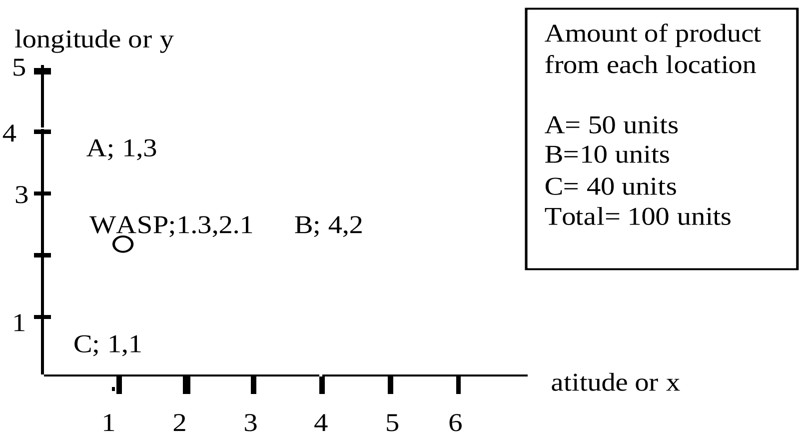
In summary, assumptions about energy efficiency of equipment and utilisation levels are important for the outcome of a study as is assumptions about cold or not cold storage. To our knowledge, little is known about utilisation levels and more information about this would be valuable.

3.7 Locations

An important step in an analysis of resource use for food is to determine transportation distances between consumers or producers etc. and therefore their geographical locations. When locations have been established it is possible to proceed with estimations about transportation distances which are the basis for estimates of resource use during transportation.

Sometimes it is straightforward to determine locations from producer information and no further analysis is needed. But as our experience shows, producers often have only vague or insufficient information about locations further up or further down the food-chain. Therefore, we present some suggestions for how to determine locations when producer information is insufficient.

1) In order to determine producer origin a method called the weighted average source point (the WASP method) can be used. Figure 1 exemplifies how a WASP is calculated.



= (50x1+10x4+40x1)/100

y = (50x3+10x2+40x1)/100

WASP; 1.3, 2.1

Figure 2: Tutorial box showing how to calculate the Weighted Average Source Points, WASP (Carlsson-Kanyama. 1997a). The points A-C are locations where food is produced and their co-ordinates are multiplied by the amount of food produced at each location. From the equations indicated in the figure, a new pair of co-ordinates is obtained that indicate the location of the WASP.

The WASP method can be used for estimating the location of farm production for a certain crop. For example, the WASP for soy bean production in USA is located at 39° 42’ N and 89° 42’ W, close to Springfield, Illinois and the WASP of German rape seed production is located at 51° 33’ N and 10° 54’ E, close to Sondershausen (Carlsson-Kanyama, 1998).

2) For determining consumer location the average consumption point in any country may be used. In Sweden, this point, i.e. the WASP for population origin, is located at 59° 2’N and 15° 11’ E close to Svennevad and is sometimes called the centre of populations mass. Some Atlases carry information about the centre of population mass and this location is commonly calculated in many countries.

3.8 Energy: basic data

Information about densities of energy carriers, inherent energy and production and delivery energy for energy carriers [14] are commonly needed for estimating resource use and emissions from food. Such information are presented in Appendix 8 where the data is organised as follows:

- **Densities of fuels** (Table 1)
- **Inherent energy and production and delivery energy for energy carriers** (Tables 2-9)
- **Energy in steam** (Table 10)
- **Conversion efficiencies** (Table 11)

Densities of fuels oils (Table 1, Appendix 8) vary between 0.84-0.94 kg per litre and density of diesel vary from 0.84-0.95 kg per litre. An extended data survey for densities of fuels could possibly reveal variations in densities for other types of fuels as well.

Estimations of the inherent energy content in energy carriers vary from e.g. from 46.1 to 51.9 MJ per kg for natural gas. Estimations of production and delivery energy for energy carriers, expressed as parts of the inherent energy content, vary too. For natural gas the fraction that should be added to the inherent energy content has been estimated to between 2 % and 9.1 % and for diesel between 6 % and 9.5 %. Inherent energy in steam (Table 10, Appendix 8) varies with temperature and pressure. Conversions efficiencies [15] reported here are between 0.89-1.04 for heat production and between 0.44-0.58 for power production. Steam production may have a conversion efficiency of 0.8-0.9. A more elaborated data survey should include estimations for conversion efficiencies for combined heat and power production as well as explanations for variations in conversion efficiencies.

Electricity in a country has got various sources of production, e.g. water or atomic power. When calculating the primary energy one has to take into account the different mix of sources as they have different conversion efficiencies. Solar power or hydropower e.g. are more efficient than electricity out of coal. In Frischknecht (1996) the calculated overall efficiency for the European mix in Switzerland is 32%. In an earlier study of (Habersatter, 1991, p. 31) it

[14] Inherent energy content is the extracted energy which remains in the product after its production and delivery to its site of use (Audesley, 1997, p..28). Production and delivery energy is the energy into the processes which extract, process, refine and deliver energy or material inputs to a process (Audesley, 1997, p..28)

[15] According to Sullivan and Heavner (1981) conversion efficiency is ” the percentage of total thermal energy that is actually converted into electricity by an electric generating plant”. Here, the term conversion efficiency means ”the percentage of total energy delivered to a plant for the production of heat, power or steam that is actually converted into heat, electricity or steam”.

was somewhat higher with 37,8 %. The effect of the choice of the electricity model in LCAs is discussed in e.g. Ménard (1998).

3.9 Transportation

Appendix 9 has energy use for transportation with various vehicles organised as follows: [16]

- **Vehicle classes for lorries** (Table 1)
- **Energy use for transportation with lorries** (Table 2)
- **Energy use for transportation with trains** (Table 3)
- **Energy use for transportation with ships** (Table 4)

Several of the reported data come from the Internet site http://www.ntm.a.se/english/default.htm. This site is run by the Swedish organisation NTM (Network for transportation and the environment). Energy use and emissions for both freight and passenger transport can be accessed and the data are updated regularly.

In general, the data in Appendix 9 shows that energy use per unit of distance and freight transported is lowest for large ships and highest for small trucks. Also, estimates of energy use per tonne-km for the same type of vehicle varies: for diesel fuelled trains this difference is almost a factor 4.

3.10 Farm inputs

A few examples of energy use for producing fertilisers are given in Appendix 10. Generally, it is the production of N-fertilisers that are the most energy consuming with 40-63 MJ per kg of N produced when conversion losses and production and delivery energy is included. The corresponding values for P-fertilisers range from 10-39 MJ per kg P and for K-fertilisers from 5-12 MJ per kg K. Production of lime are in the range of 1-5 MJ per kg output.

Energy use for production of pesticides may range from 118-400 MJ per kg active ingredient according to examples from pesticides used in wheat production (Audesley, 1997, p. 34). This figure includes conversion losses and production and delivery energy.

Estimations of energy use for seeds and plants are not included but should be part of a more extensive data survey.

4. Allocation

Allocation problems occur when dealing with multifunctional processes– a process that fulfils more than one function. Examples are a production process with more than one product, a waste management process dealing with more than one product, a waste management process dealing with more than one waste flow, or a recycling process providing both waste management and material production (Ekvall, 1999, Paper VI, p. 2).

When analysing the resource use of food, such problems may occur for combined meat and milk production, for oil extraction (oil and meal) and for cheese production (cheese and whey). It is important to remember that the same output may or may not be considered as a product depending on time, time-scale and location. In situations when fertilisers are scarce,

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[16] Energy use is given as process energy.

animal manure can be considered as a valuable product, while the opposite situation may be the case when artificial fertilisers are abundant.

The International Organisation for Standardisation (ISO) has presented a standard for Life-Cycle Inventories (LCI) which may be of help for those wanting to proceed with estimations of resource use of foods. This standard–ISO 14041–requires that the following procedure should be used for allocation in multi-functional processes (from Ekvall, 1999, Paper VI, p. 2):

- Allocation should be avoided whenever possible, either through division of the multi-functional process into sub processes and collection of separate data for each sub-process, or through expansion of system boundaries until the same functions are delivered by all systems compared.
- Where allocation cannot be avoided, the allocation should reflect the physical relationships between the environmental burdens and the functions i.e., how the burdens are changed by quantitative changes in the functions delivered by the system.
- Where such physical relationships alone cannot be used as the basis for allocation, the allocation should reflect other relationships between the environmental burdens and the functions.

Using the example of oil extraction (resulting in oil and meal), the ISO standard could be interpreted as follows:

The first principle could be applied if resource use of an alternative to oil was known (e.g. butter). Resource use for butter production could be subtracted from the resource use for oil production and the resulting level would be relevant for meal.

The second principle hardly seem applicable to oil extraction. The third principle would include various allocation options such as economic value, energy content in the outputs or by allocation by mass. Carlsson-Kanyama (1998) allocated emissions for oil and meal based on the weight of the respective outputs. This method would fall into the last category in the ISO standard.

In practice, allocation between meat and milk in combined meat and milk production has been carried out according to the principle of "biology" which is based on the casual relationship between fodder input and outputs of milk and meat. This resulted in 85 % allocation to milk and 15 % to meat (Cederberg, 1998, p. 13). This method seems to fit well into the description of the second recommendation in the ISO standard. Moller and Hogaas (1997) showed two possible ways of allocating meat and milk in combined meat/milk production systems with very similar outcomes (Table 18).

Table 18: Allocation according to biological need and economic value (Moller and Hogaas, 1997).

	Biological need	Economic value
Meat	65	66
Milk	35	34

5. Conclusions

- The data presented in this report and its' appendixes can be used for quick and rough estimates of the energy use for various food products along the whole production chain.

- Estimates such as the ones presented here, can be used to quickly illustrate some major differences in energy use for foods. Such differences are e.g. animal contra vegetable products, products cultivated in greenhouses or in the open, or fresh versus canned or frozen products.

- Estimates based on data presented here can be used for a simplified Life-Cycle Assessment (LCA). A detailed LCA requires, however, system specific data. [17]

- More data on food losses, storage times, storage energy and food processing would be particularly welcome for further studies.

- Data collections of the kind presented here should be used with care; we strongly recommend anyone who wants to make their own calculations to consult the original references.

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