Chapter 2
The Food and Energy Connection

As mentioned in the previous chapter, energy from fossil fuel is now used both directly and indirectly at multiple stages of the food production and supply chain, from primary production, processing, retailing, transportation and ultimately by the consumer. This relationship is illustrated by the following extract from the work of Canning and coworkers, using a hypothetical purchase of a non-organic salad mix by a consumer living on the East Coast of the US

> In this case, fresh vegetable farms in California harvest the produce to be used in the salad mix a few weeks prior to its purchase. The farms' fields are seeded months earlier with a precision seed planter operating as an attachment to a gasoline-powered farm tractor. Between planting and harvest, a diesel-powered broadcast spreader applies nitrogen-based fertilizers, pesticides, and herbicides, all manufactured using differing amounts of natural gas and electricity and shipped in diesel-powered trucks to a nearby farm supply wholesaler. Local farmers travel to the wholesaler in gasoline-powered vehicles to purchase farm supplies. The farms use electric-powered irrigation equipment throughout much of the growing period. At harvest, field workers pack harvested vegetables in boxes produced at a paper mill and load them in gasoline-powered trucks for shipment to a regional processing plant, where specialized machinery cleans, cuts, mixes, and packages the salad mixes. Utility services at the paper mill, plastic packaging manufacturers, and salad mix plants use energy to produce the boxes used at harvest and the packaging used at the processing plant, and for processing and packaging the fresh produce. The packaged salad mix is shipped in refrigerated containers by a combination of rail and truck to an East Coast grocery store, where it is placed in market displays under constant refrigeration.
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> To purchase this packaged salad mix, a consumer likely travels by car or public transportation to a nearby grocery store. For those traveling by car, a portion of the consumer's automobile operational costs, and his or her associated energy-use requirements, help facilitate this food-related travel. At home, the consumer refrigerates the salad mix for a time before eating it. Subsequently, dishes and utensils used to eat the salad may be placed in a dishwasher for cleaning and reuse—adding to the electricity use of the consumer's household. Leftover salad may be partly grinded in a garbage disposal and washed away to a wastewater treatment facility, or disposed, collected, and hauled to a landfill (Canning et al. 2010).

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Energy Use in Primary Food Production

Direct fossil energy inputs into agriculture have generally been outweighed by yield improvements that deliver positive energy ratios, i.e., the energy content of the crop is greater than the energy utilized to produce that crop. However, when the embodied energy, i.e., energy utilized over the life cycle of the crop is considered, in some instances more energy can be used than is contained in the final product, as reviewed by Woods et al. (2010) for a range of crops in the UK. These studies used a standard ‘cradle to grave’ approach for life cycle assessment (LCA) of environmental impacts of a process or product. The review covered three field crops (bread wheat, oilseed rape and potatoes), four meats (beef, poultry, pork and lamb), milk and eggs, and tomatoes as the main protected crop. Apples and strawberries were also analyzed. Primary production to the farm gate was studied to provide the LCA.

For arable crops, energy inputs to produce the UK’s main crops range from 1 to 6 GJ t^{-1} (Table 2.1). The authors examined conventional and organic farming methods, though direct comparisons methods can be problematic, since it appears that reduced direct use of fertilizers in the latter methods, is balanced out by lower yields. In general, oilseed rape is the highest energy consumer, given low yields and high fertilizer use, but the grain is more energy dense than cereals or legumes. For production of bread wheat, used as a proxy for cereals in the study, half the energy used is for fertilization, of which 90 % of the energy is in nitrogen production. Pesticide manufacture, by contrast, accounts for less than 10 % of the energy use. Potato cropping is more energy intensive than cereals and legumes due to the energy used for cool storage for long periods. However, because potatoes are a high yielding crop, they have a lower energy use per tonne harvested. Interestingly, if the energy use per tonne is calculated on a dry biomass basis, the energy intensity of potatoes is much higher since they contain 80 % water, compared to 15–20 % for wheat grain.

Although fossil fuels remain the dominant source of energy for agriculture, the mix of fuels used differs owing to the different fertilization and cultivation

Table 2.1 Primary energy used in arable crop production

	Primary energy used GJ t^{-1}	
	Non-organic	Organic
Bread wheat (UK)	2.52	2.15
Oilseed rape (UK)	5.32	6.00
Potatoes main crop (UK)	1.46	1.48
Feed wheat (UK)	2.32	2.08
Winter barley (UK)	2.43	2.33
Field beans (UK)	2.51	2.44
Soya beans (US)	3.67	3.23
Sugarcane (Brazil)	0.21	
Maize (US)	2.41	

Adapted from Woods et al. (2010)

Table 2.2 Energy used in animal production at commodity level in the UK

Commodity	Poultry	Pig meat	Beef	Lamb meat	Milk	Eggs
Unit	1 t ecw	1 t ecw	1 t ecw	1 t ecw	m^3	1 t
Primary energy (GJ)	17	23	30	22	2.7	12
Feed (%)	71	69	88	88	71	89
Manure and litter (%)	2	1	1	1	0	−4
Housing (%)	1	4	0	0	3	3
Direct energy (%)	25	26	11	11	26	12

ecw edible carcass weight (killing out percentage × live weight), slaughter not included
1 m^3 milk weighs about 1 tonne and 15,900 eggs weigh 1 tonne
Adapted from Woods et al. (2010)

requirements of individual crops and different approaches in different parts of the world (Woods et al. 2010). For example, in Europe, nitrogen fertilizer production uses large amounts of natural gas, and can account for more than 50 % of total energy use in commercial agriculture. Fossil oil accounts for between 30 and 75 % of energy inputs of UK agriculture, depending on the cropping system. However, in China 80 % of the energy for nitrogen fertilizer production comes from coal. In addition, in most regions, the embodied energy in farm machinery is an overhead of 40 % of diesel used for production.

The energy used per tonne of animal production is higher than that used for cropping (Woods et al. 2010), since animals are fed on crops and convert crop energy into higher quality protein and nutrients (Table 2.2). Feed provision is the dominant term in energy use (average of about 75 %). Direct energy use includes managing field stock, heating for young birds and piglets, and ventilation for pigs and poultry. Housing contributes a small fraction of total energy inputs, and is lower for more extensive systems, like free-range hens. For egg production, the energy demand of manure management is more than offset by the value of chicken manure as a fertilizer, hence this can have a net negative value for energy use (Table 2.2). There is less variation in the energy mix for livestock production. About a third comes from oil and a third from natural gas. 70–90 % of the energy utilized is for feed production and supply.

Energy Contribution to Food Processing

Post-producer

According to a recent USDA report processing industry energy use for cooking, cooling, and freezing contributes an average share of 15–20 % of total US food system energy use (Canning et al. 2010). The analyses used two US benchmark input-output accounts and a national energy data system to review energy usage and change in food production and consumption in the US over the decade from

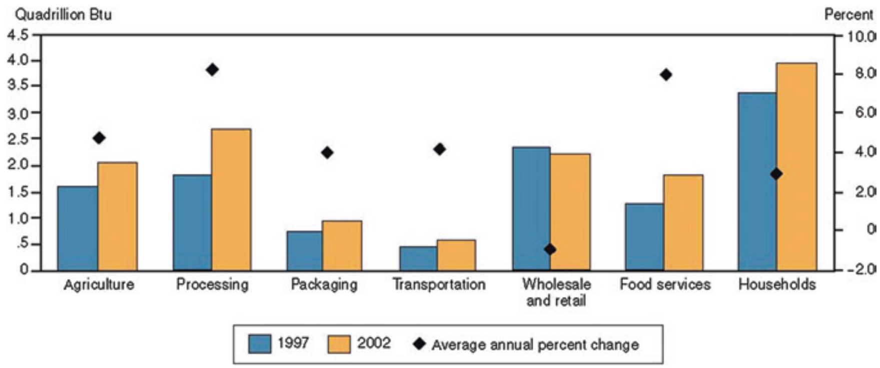

Fig. 2.1 Change in US energy consumption, by stage of production from 1997 to 2002. Adapted from Canning et al. (2010)

1997 to 2007 (Fig. 2.1). Half of the growth in food-related energy in the first five years of the decade was explained by a shift from human labour to energy services driven activities. Both households and food service industries outsourced manual food preparation and clean-up to food processing manufacturers, which typically used energy-based machinery to complete the tasks.

A time-use study of adults between ages 18 and 64 demonstrated that average time/day spent on cooking and cleaning at home was reduced from just over one hour in 1965 to half an hour in 1995 (Cutler et al. 2003). The decrease in food preparation time coincides with the growth in demand for convenience foods which require more processing, industrial preparation and packaging than food prepared at the household level. Food service establishments like restaurants and convention centres also increasingly outsource food preparation to the food processing industry. As a result energy flows through the food processing industries have increased in the US at an average rate of 8.3 % per annum between 1997 and 2002 (see Fig. 2.1). The USDA estimates that this flows through on a per capita basis to the equivalent of 24 gallons (90.8 L) of petroleum per person per year (Canning et al. 2010).

Consumer or Household/Kitchen Operations

The USDA report cited above also refers to the 2001 Residential Energy Consumption Surveys (RECS), used to obtain estimates of food-related household operational expenditures in 2002. According to these data, cooking (electric range, oven, microwave, toaster oven, and coffee makers) accounted for 6.5 %, refrigeration 14 %; freezing, 3.4 %; dishwashers, 2.5 % of household energy use. Combined, these sources accounted for 10 % energy use in the US food system and 26 % of the total proportion of household electricity in 2001.

Wholesale/retail activities account for about 4 % of the energy use in the US food system. These decreased by 1.1 % per annum from 1997 to 2001, probably driven by consolidation in the grocery sector.

Transportation

The concept of 'food miles' has become popular in the community as a way of assessing energy use for consumer purchasing decisions. However, some findings (Canning et al. 2010; Pelletier et al. 2011) suggest that energy flows associated with the commercial transportation of food represent less than 5 % of total energy use by the overall food system. This is largely because the bulk of food supplies are transported domestically in the US by road and rail and internationally by rail or ships, the latter being relatively energy efficient. Of course, this share of energy use is considerably higher for some food categories, such as fresh fruits and vegetables, and produce like fish, which require refrigeration or freezing and airfreight.

To maximize net energy savings through reliance on local food production, the local farm, agribusiness, and processing industries would need to be at least as energy efficient as the distant industry alternatives that they replace, whether produced domestically or in a foreign country.

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