MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Research and Development

Final Project Report

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Project title	Energy use in organic farming systems
MAFF project code	**OF0182**
Contractor organisation and location	ADAS Consulting Ltd ADAS Terrington Terrington St Clement Kings' Lynn, Norfolk, PE34 4PW.
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Executive summary (maximum 2 sides A4)

Organic farming research is funded by MAFF in support of its objective "*to sustain and enhance the rural and marine environment and enjoyment of the amenities they provide and to promote forestry*". MAFF Research Strategy 1996-2000 acknowledges that there is an environmental benefit from organic farming methods but there is a need to understand this more fully. One of the possible benefits from organic farming is a reduced, or more efficient, use of energy in agriculture.

The main objective and deliverable of study OF0182 was to develop a model of energy inputs in organic farming systems. To illustrate the potential of the model, it was used to contrast organic with similar conventional systems and to highlight important differences. This was presented as a detailed written report (49 pages) to MAFF and is summarised in this document. The report and model were delivered to MAFF in March 2000.

A previous study, completed by Phil Metcalfe of ADAS, in 1996, for MAFF ARP Division, titled "A Comparison of Energy use in Organic and Conventional Agricultural Production Systems", compared direct and indirect energy use in simple individual crop and livestock enterprise models. These were combined to give whole-system models covering dairy, beef and arable farming. These systems were presented as organic conversion scenarios in the MAFF booklet "Organic Conversion Information Service" (1996). Project OF0182 updates the models developed in 1996 and expands the study to include upland beef and sheep, and vegetables. The dairy, vegetables, arable and upland beef/sheep models are based on the MAFF funded studies OF0146, 0126, 0145 and 0147 respectively. The study also included a consideration of food distribution costs and the possible substitution of labour for energy.

Basic information on energy inputs (pesticides, machinery, fertilisers and road transport) was entered into an Excel spreadsheet. A worksheet was created for each crop or livestock enterprise involved in the farming systems to be modelled. All inputs were detailed on these sheets and links established to the input data sheets to enter the energy data. Physical output was entered into these worksheets and the metabolisable energy (ME) content of the output calculated. The energy ratio "E1" (ME output/input energy) was calculated. Worksheets were then created for each of the farming systems to be studied. These collected the data from the individual crop/livestock worksheets and applied them to model farms of sizes typical for the systems to give overall energy inputs, outputs and ratios. The links between all sheets are live allowing for easy updating of basic information and modelling of the effect of, for example, increasing the number of mechanical weeding operations, or of increasing or decreasing the output.

The dominant energy inputs in conventional agriculture are indirect energy for the manufacture and transport of fertilisers, particularly nitrogen, and indirect energy for the manufacture and transport of pesticides. These together account for around 50% of the total energy input to a potato or winter wheat crop, and as much as 80% of the energy input into some vegetable crops.

Organically grown crops require around 50% of the energy input per unit area than do conventional crops, largely because of lower, or zero, fertiliser and pesticide energy inputs. However, the generally lower yields of organic crop and vegetable systems reduce the advantage to organic when energy input is calculated on a unit output basis. In stockless arable crop rotations, the inclusion of fertility building crops and winter cover crops, that have energy inputs but no direct outputs, can result in a lower whole-rotation energy efficiency from organic methods. In livestock systems, where the fall in output may be less than in arable, and there are no dedicated fertility building crops, overall energy efficiency is greater in organic than in comparable conventional systems.

These conclusions were made using average yield data in the model and need to be interpreted with caution. On more fertile soil, where the yield difference with conventional arable production is smaller, organic systems would perform relatively better. The converse would occur on poorer soils. Also, in practice, energy inputs for cultivations and weed control will vary with soil type, weather, weed spectrum and population. The average data presented in the report are illustrative and are not definitive. The strength of the model is that it can be used to simulate many different management systems and yield expectations.

Transport energy is most likely to differ significantly between organic and conventional systems in vegetable production. This is because of the current relatively small scale of organic production and the need for regular supplies to retailers. Energy costs for transport from farm to retailer distribution centre were considered for a range of scenarios. Compared to large-scale conventional vegetable production, the modelling suggests that there is scope to reduce transport energy costs by around 40% by group transport to packers or by local sale. Importing from northern Europe to the English midlands added 44% to transport energy costs, and from southern Europe added 352% to costs. As none of these scenarios include transport from distribution centre to retail outlet, as would be expected, the local sale option had the lowest overall transport energy cost. As for the energy efficiency results, these are illustrative and the model can be used to compare specific combinations of load size, distance travelled and numbers of journeys.

The project did not identify any significant opportunities for replacement of energy inputs by labour. This may be possible for weed control in some situations but, apart from the use of flame weeders, this is only a small proportion of the total energy input. More importantly, weed control is time sensitive; therefore for large-scale production it must be mechanised. There is also a shortage of suitable and willing labour for this type of work in many places.

Scientific report (maximum 20 sides A4)

1. INTRODUCTION

A previous study completed by ADAS in 1996 for MAFF ARP Division, titled “A Comparison of Energy use in Organic and Conventional Agricultural Production Systems”, compared direct and indirect energy use in simple individual crop and livestock enterprise models. These were combined to give whole-system models covering dairy, beef and arable farming. These were presented as organic conversion scenarios in the MAFF booklet “Organic Conversion Information Service” (1996).

Project OF0182 updates the models developed in 1996 and expands the study to include upland beef and sheep and vegetables. The dairy, vegetables, arable and upland beef/sheep models are based on the MAFF funded studies OF0146, 0126, 0145 and 0147 respectively. The study was expanded to include a consideration of food distribution costs and the possible substitution of labour for energy.

1.1 Purpose

To examine the energy inputs in organic farming, to contrast with similar conventional systems, to highlight important differences and to consider ways of minimising energy-intensive practices.

1.2 Objective

To update an existing model of energy use in farming systems and expand to cover conventional and organic upland beef and sheep, and field vegetables:

1) To check the agronomic assumptions in the existing models, particularly for inputs, cultivations, and to incorporate any updates into the models.

2) Produce new models for conventional and organic upland livestock and field vegetables. The conventional field vegetables model is to be for individual crops in order to reflect specialisation in the industry, the organic model is to be based on the OF0126 crop rotation with the longest fertility building period.

3) Apply the model predictions to the data from the MAFF funded organic conversion projects OF0145 (stockless arable), OF0147 (upland beef and sheep), OF0146 (dairy) and OF0126 (field vegetables, rotation with the longest fertility building period only).

Objective 3 is as agreed in the CSG7. In practice, rather than applying the model predictions to the data from the MAFF studies, the models have been based on the crop/stock rotations/practices of these projects, mainly because these were the only, or most reliable sets of data to use.

2. ENERGY AND AGRICULTURE

2.1 Direct energy inputs

Direct energy inputs to farming are in the form of fuel oils, electricity, gas, etc. which are consumed on the farm. These can be considered as a variable input directly proportional to the size of the respective enterprises. These costs were calculated from work rates and fuel consumptions for individual machinery combinations.

2.2 Indirect energy inputs

In addition to the fuel directly used at farm level, indirect energy is used in agriculture in the form of other inputs and intermediate flows. The main categories of indirect energy are:

2.2.1 Fertilisers

The energy used in the manufacture, packaging, storage and transport to the farm of fertilisers.

2.2.2 Pesticides

The energy used in the manufacture, packaging, storage and transport to the farm of herbicides, pesticides and fungicides.

2.2.3 Field machinery

The energy used in the manufacture, transport and maintenance of machinery used on farms, including spare parts.

2.2.4 Intermediate inputs

Chemically treated crop seeds, bought-in livestock, feedstuffs etc. are intermediate products which can be attributed an energy content based upon the energy from all the previous categories used in their production.

2.3 Basic and variable energy inputs

White (1981) proposed the application of energy inputs in the same way that farm management uses gross margins. This has basic inputs which are incurred irrespective of output, and variable inputs which are associated with a particular level of output.

This technique can be used when estimating the energy inputs for different enterprises. Organic farming systems tend to substitute additional machinery operations for variable inputs, particularly for the reduced pesticide use compared with conventional systems.

2.3.1 Fertilisers

Data on energy use for the manufacture of fertiliser by type has been taken from a number of sources (Table 1). These data have been used to update the 1996 model where appropriate.

Table 1. Energy used for the manufacture of fertilisers.

Group	Energy MJ/kg	Reference
Ammonium nitrate	49.1	Patyk & Reinhardt (1997)
P_2O_5 (rock)	7.02	Fluck (1992a)
P_2O_5 (acid)	17.7	Patyk & Reinhardt (1997)
K_2O	10.5	Patyk & Reinhardt (1997)
Lime	2.39	Patyk & Reinhardt (1997)

2.3.2 Machinery

The energy cost of machinery consists of:

a) Energy in manufacture.

Earlier studies used the ratio *Gross National Product: National Energy Consumption* to estimate the energy content of machinery. A more precise method has been used for this study. Indirect energy has been calculated from machine weights using a factor of 86.77 MJ/kg (Bowers, 1992). This was based upon UK data on energy requirements for raw materials (Boustead & Hancock, 1979) and energy added in manufacture and transport. This also has the advantage that new data can be easily introduced to update the model.

b) Energy in repairs

The energy input into maintenance and repair throughout a machine's life varies for different types of machine (Table 2). This has been calculated as a ratio of the total energy in manufacture (Bowers, 1992).

Table 2. Energy used in repairs in relation to manufacturing energy input (Bowers, 1992).

Machine	Ratio of energy in repairs and maintenance to manufacturing energy
Tractors	0.49
Combine harvesters	0.24
Ploughs	0.97
Planters	0.43
Cultivators	0.58
Disc harrows	0.61
Mowers	1.44
Balers	0.39
Forage harvesters	0.39
Rotary hoes	0.59
Sprayers	0.37
Average	0.55

c) Energy in distribution

A further sum, equal to 8% of the manufacturing energy, has been added to allow for distribution of the manufactured product (Bowers, 1992).

For fixed equipment, such as drying and storage facilities, the GNP: National Energy Consumption ratio method was retained. The long design life of these facilities results in a low contribution to the total energy cost so any variance will have little overall impact.

2.3.3 Pesticides

Energy for the manufacture and distribution of pesticides came from two sources (Table 3). The more recent European data of Meir-Ploeger *et al.* is in broad agreement with the earlier Helsel paper.

Table 3. Energy used for the manufacture of pesticides.

Pesticide	Typical energy in manufacture and delivery MJ/kg	Range MJ/kg	Source
Herbicide	238	80 - 454	Helsel (1992)
Pesticide	199	58 - 454	Helsel (1992)
Fungicide	92	61 - 115	Helsel (1992)
Pesticides (general)	315		Meir-Ploeger *et al*. (1996)

2.3.4 Road transport

Like machinery, road transport uses fuel directly and also has an energy cost in manufacture and maintenance. As for farm machinery, calculation of indirect energy was from machinery mass (Bowers, 1992). The direct and indirect energy per tonne per kilometre was calculated. Details are not included here for lack of space but have been presented to MAFF in the full report.

3. METHOD

For crop or livestock enterprises, the direct and indirect components of energy were calculated on a per hectare or per head basis. Crop yields and livestock outputs were as presented by Lampkin & Measures (1999) for organic, and Nix (1999) for conventional. Where a choice was given, the average output was used. Detailed inputs were based on information from the four MAFF-funded conversion projects detailed above, from ADAS internal publications and from personal communications with colleagues. The inputs and their frequencies are by necessity averages. In practice, inputs such as mechanical weed control will vary depending on soil type, weather, previous cropping, etc.

The model was progressed in three stages:

1. Basic information on energy inputs was entered into four worksheets (pesticides, machinery, fertilisers and road transport) in an Excel spreadsheet. These sheets are not printed in full in this report but parts are included in the text tables.

2. A worksheet was created for each crop or livestock enterprise involved in the farming systems to be modelled (including fodder crops for livestock, Set-aside, winter cover crops and fertility building crops). All inputs were detailed on these sheets and links established to the input data sheets to enter the energy data. On each worksheet, indirect and direct energy inputs were totalled separately. Physical output was entered into these worksheets and the metabolisable energy (ME) content of the output calculated (White, 1981). The energy ratio E1 (ME/input Energy) was then calculated.

3. A worksheet was then created for each of the farming systems to be studied. These collected the data from the individual crop/livestock worksheets and applied them to model farms of sizes typical for the systems to give overall energy inputs, outputs and ratios. These sheets are not printed in full in this report but parts are included in the text tables.

The links between all sheets are live so that the completed spreadsheet is fully interactive allowing changes at any level to the model outcomes. In particular, this allows for easy updating of basic information and modelling of the effect of, for example, increasing the number of mechanical weeding operations, or of increasing or decreasing the output.

3.1 Arable and vegetables

In addition to crop variable inputs such as agrochemicals, fertilisers and seed, cultivations were tabulated. For harvesting, the operation of harvesters and collection equipment were included. On-farm processing of products was included where appropriate, e.g. grain drying. The energy cost of off-farm processing and packing of produce was not included, apart from the consideration of transport (see 3.4).

3.2 Fertility building crops, winter cover crops and set-aside

Worksheet models were produced for fertility building crops, winter cover crops and set-aside. These can then be built into the whole system worksheets with more flexibility, and their relative contributions can be clearly seen.

3.3 Livestock enterprises

Livestock enterprises were modelled in a similar manner but on a per-head rather than per-hectare base, as is usual in gross margin assessments of enterprises.

Intermediate inputs such as forage, cereals and store animals were included. Where possible, these were entered as the energy used in their production where these could have been produced on-farm. The associated energy costs, along with silage and hay costs, are included in the livestock calculations.

Outputs were calculated and entered as metabolisable energy, so that each enterprise could be summarised in energy ratio terms. This gave a single figure of energy efficiency for comparison between farming systems.

3.4 Transport to distribution centres

An additional objective of the research was to determine the energy component of the distribution chain for organic material.

The variables which affect the transport energy in distribution are:

- Load volume and weight.
- Transport distance.
- Type of vehicle.

Load weight depends upon:

- Production level.
- Collection frequency.
- Bulk density.
- Container system.

3.4.1 Cereals, pulses and root crops

Quantities produced, even in organic production, are large relative to the maximum transport load size of 20 t.

Potatoes and other dried or long storage life products are similar in terms of volume. They do not spoil in storage over a week or so and can be safely transported in bulk at high densities. The payload weight for bulk transport was assumed to be 20 t for both organic and conventional.

3.4.2 Vegetables

These more perishable products were assumed to be delivered on a daily or two-day cycle to meet multiple retailer Quality Assurance requirements. The current scale of organic vegetable production was assumed to be such that loads of less than 20 t would be required to be delivered. The lower bulk density of the produce and fragile nature was assumed to require intermediate containerised transport. This was assumed to reduce the net weight of product that was transported.

A payload weight of 5 t was assumed for organic compared with 20 t for conventional crops.

Organic produce for multiple retailers was assumed to be collected at a central depot into sufficient quantities to provide continuity of supply and consistency of quality. Premises for the packing and distribution of this quality of product must be certificated by an organic sector body. This results in fewer locations, with consequent longer average distances for fresh material to be transported.

The difference between conventional and organic production was assumed to occur up to the delivery to the retail distribution centre. Thereafter, it was assumed that the smaller quantities would be carried on mixed loads at no extra transport cost per tonne per kilometre over complete loads of conventional product.

Transport of fresh vegetables is likely to show the greatest differences in transport costs. To illustrate the energy cost implications, seven scenarios were compared:

1. Large scale conventional or organic produce by bulk load to a packing centre and then delivery to a distribution centre.
2. Organic produce taken to a local co-operative for loading, then by bulk load to a packing centre and then delivery to a distribution centre.
3. Organic produce taken direct to a packing centre, then by bulk load to a distribution centre.
4. Conventional or organic produce collected by the packer, then to a distribution centre.
5. Organic produce imported from northern Europe.
6. Organic produce imported from southern Europe.
7. Organic produce delivered to a local wholesaler for local shops.

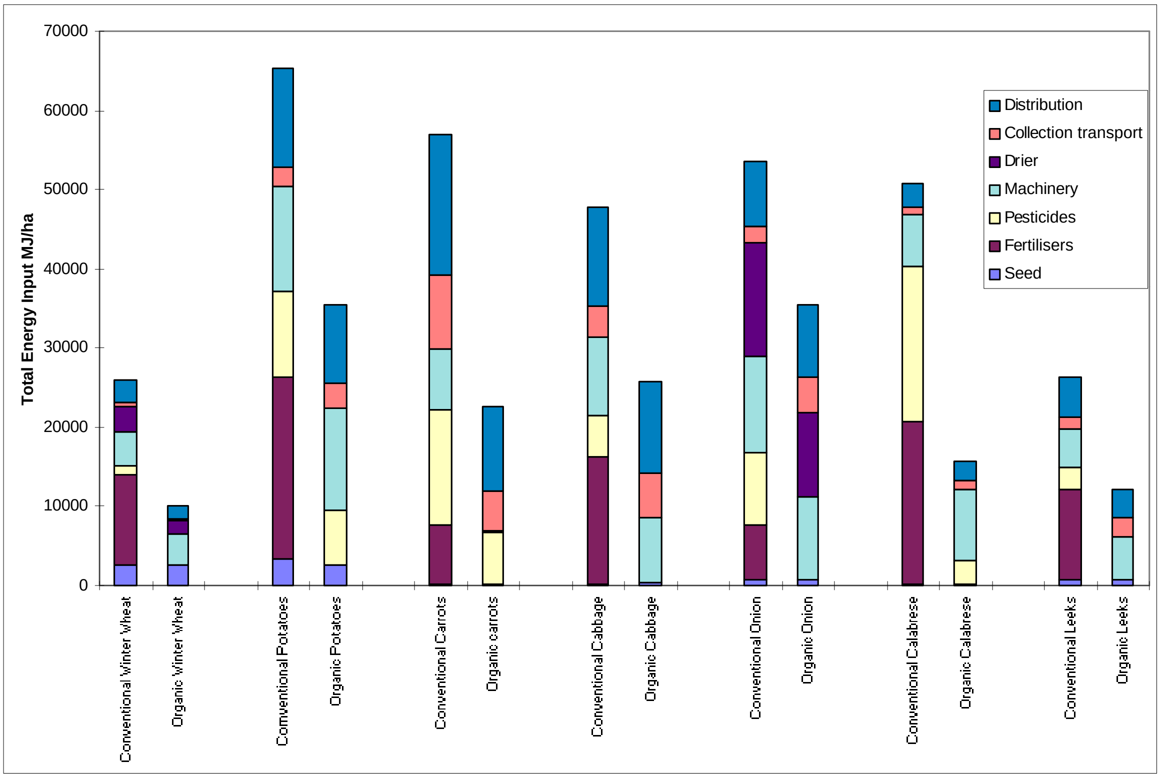
4. RESULTS

These results relate to the use of average yield data in the model and need to be interpreted with caution. On more fertile soil, where the yield difference with conventional arable production is less, organic systems would perform relatively better. The converse would occur on poorer soils. Also, in practice, energy inputs for cultivations and weed control will vary with soil type, weather, weed spectrum and population. The average data presented in this report are illustrative and are not definitive. The strength of the model is that it can be used to simulate many different management systems and yield expectations.

4.1 Energy costs of inputs to arable and vegetable crops

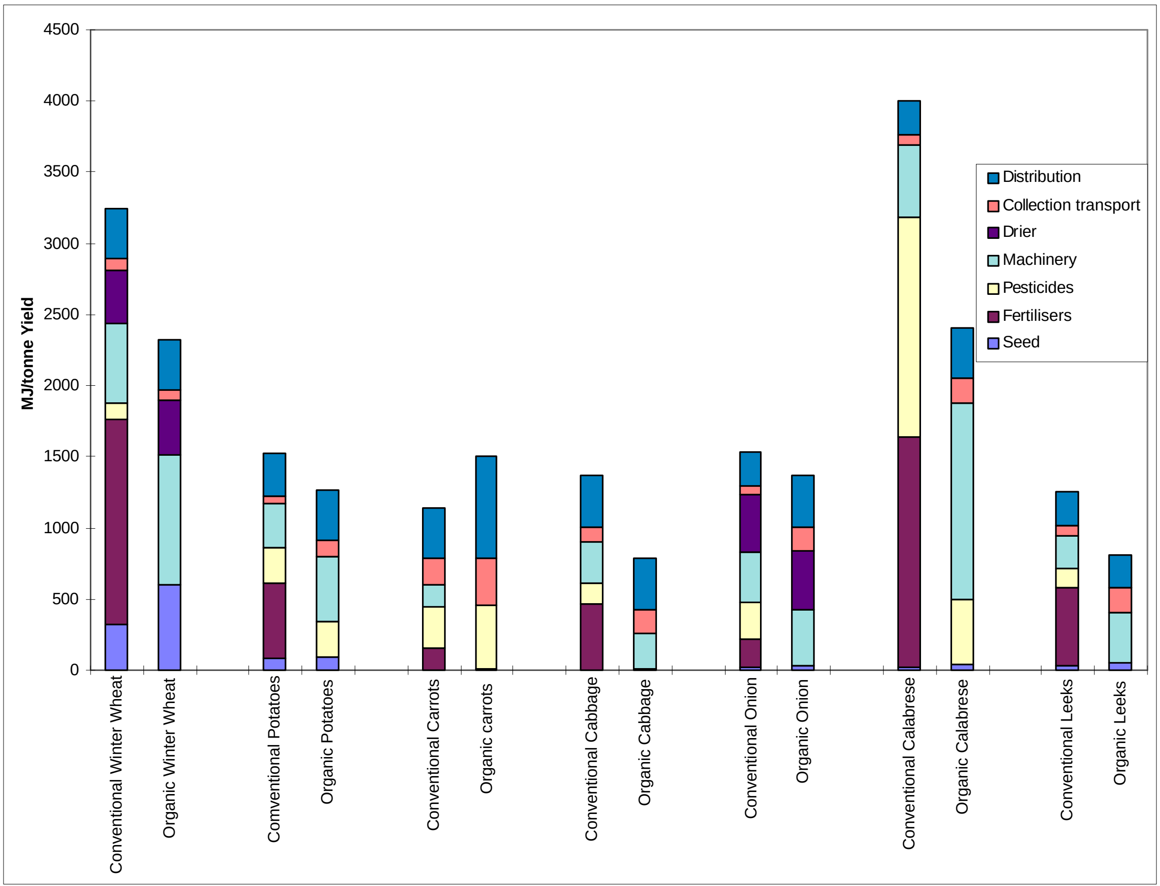
The relative contribution of each component of energy input, up to delivery to a distribution centre, is shown on an area basis for a selection of crops in Figure 1.

Figure 1. Energy input by category on an area basis (MJ/ha)**.**



Organically grown crops have a lower energy input per unit area than conventional crops, largely because of lower fertiliser and pesticide inputs. However, applying typical yields for conventional and organic crops, the effect on energy input per unit output of the lower yields generally obtained with organic production is illustrated in Figure 2.

Figure 2. Energy input by category on a unit output basis (MJ/t yield)

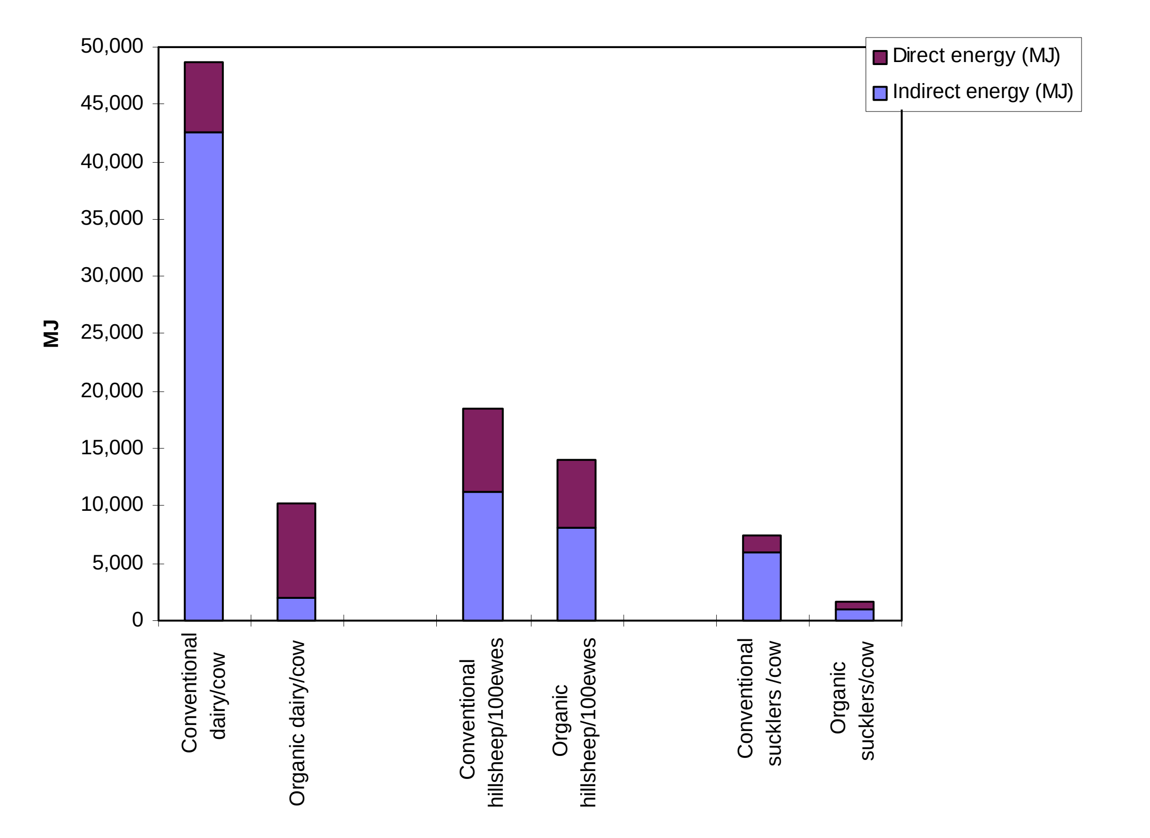


Most crops still show a lower energy per unit from organic production, but the difference is reduced due to the lower organic output. Organic carrots show a greater energy use than conventional, largely because of the energy cost of flame weeding that is included in the pesticide input category, and on higher distribution energy costs. These figures have been calculated on average yield data. On more fertile soil where the difference with conventional production is less, the energy per unit output would be more favourable for organic. The converse would occur on poorer soils. Also, the transport costs for organic vegetable crops are higher as a result of smaller loads, greater distances to certificated organic packing facilities.

4.2 Energy costs of inputs to livestock enterprises

Energy input is lower in organic systems, particularly dairy (Figure 3).

Figure 3. Direct and indirect energy inputs into livestock enterprises.



4.3 Farming systems models

Results from the whole-farm systems are summarised below (Tables 6 to 17).

Table 6. Conventional mainly arable (1996 OCIS booklet model) - energy inputs, outputs and ratio.

	Area	Total Energy Input	Indirect Energy	Direct Energy	Total Output
	ha	MJ	MJ	MJ	MJ
Farm area	260				
Crop area	260				
Total energy (MJ)		5,401,069	3,907,747	1,493,321	19,358,961
Per unit area (MJ/ha)		20,773			74,458
Overall Energy Ratio E1		3.58			
Percentage		100	72	28	

Table 7. Organic mainly arable (1996 OCIS booklet model) - energy inputs, outputs and ratio.

	Area ha	Total Energy Input MJ	Indirect Energy MJ	Direct Energy MJ	Total Output MJ
Farm area	260				
Crop area	260				
Total energy (MJ)		1,589,203	694,342	994,862	8,811,184
Per unit area (MJ/ha)		6,112			33,889
Overall Energy Ratio E1		5.54			
Percentage		100	37	63	

Table 8. Conventional stockless arable (1996 OCIS booklet model) - energy inputs, outputs and ratio.

	Area ha	Total Energy Input MJ	Indirect Energy MJ	Direct Energy MJ	Total Output MJ
Farm area	140				
Crop area	140				
Total energy (MJ)		2,950,155	2,049,613	900,543	15,274,067
Per unit area (MJ/ha)		21,068			109,075
Overall Energy Ratio E1		5.18			
Percentage		100	69	31	

Table 9. Organic stockless arable (1996 OCIS booklet model, which did not include winter cover crops) - energy inputs, outputs and ratio.

	Area ha	Total Input MJ	Indirect Energy MJ	Direct Energy MJ	Total Output MJ
Farm area	140				
Crop area	140				
Total energy (MJ)		1,293,966	468,797	825,169	5,704,806
Per unit area (MJ/ha)		9,243			40,749
Overall Energy Ratio E1		4.41			
Percentage		100	36	64	

Table 10. Organic stockless arable with vegetables (as in OF0145) - energy inputs, outputs and ratio.

	Area **ha**	**Total Energy Input** **MJ**	**Indirect Energy** **MJ**	**Direct Energy** **MJ**	**Total Output** **MJ**
Farm area	140				
Crop area	196				
Total Energy (MJ)		1,393,719	428,728	964,990	6,151,328
Per unit area (MJ/ha)		9,955			43,938
Overall Energy Ratio E1		4.41			
Percentage		100	31	69	

Table 11. Organic stockless arable with potatoes (as in OF0145) - energy inputs, outputs and ratio.

	Area **ha**	**Total Energy Input** **MJ**	**Indirect Energy** **MJ**	**Direct Energy** **MJ**	**Total Output** **MJ**
Farm area	140				
Crop area	196				
Total energy (MJ)		1,535,202	578,215	956,987	6,709,928
Per unit area (MJ/ha)		10,966			47,928
Overall Energy Ratio E1		4.37			
Percentage		100	38	62	

Cropped area appears larger than farmed area where the system includes winter cover crops, in effect double cropping.

The two OF0145 rotations have an energy input of 9,900 MJ/ha and 10,900 MJ/ha compared with 21,000 MJ/ha in the conventional stockless rotation. However, energy output per unit area was also more than halved at 43,900 MJ/ha and 47,900 MJ/ha in the organic compared with 109,000 MJ/ha in the conventional stockless rotation. The fall in output was greater than the fall in inputs resulting in a lower energy ratio from the organic rotations. This was due to the lower yields, the inclusion of annual fertility building crops in place of cash crops, and the addition of winter cover crops. The last two categories incur energy costs with no direct harvested output.

Conventional cereal production relies heavily on nitrogen fertiliser which is the dominant indirect energy input. When this is absent in an organic system, the energy used in crop drying assumes greatest significance. This is a variable input which is yield dependent. This results in the majority of energy input being direct in the organic arable systems compared with indirect in the conventional systems.

Table 12. Organic vegetables (rotation as in OF0126) - energy inputs, outputs and ratio.

Organic vegetables	Area ha	Total Energy Input MJ	Indirect Energy MJ	Direct Energy MJ	Total Output MJ
Farm area	4				
Crop area	5				
Total energy (MJ)		39,061	11,860	27,202	207,291
Per unit area (MJ/ha)		9,748			51,732
Overall Energy Ratio E1		5.31			
Percentage		100	30	70	

As large-scale conventional vegetable production is specialised on individual crops or crop types, with no typical rotation, the organic rotation energy ratio has been compared with individual crop energy ratios for conventional vegetables (Table 13).

In organic vegetable growing, the considerable herbicide input is replaced by increased machinery energy cost for mechanical weeding. For carrots, one pass of a flame weeder has also been included. This consumed more energy than the herbicide in the conventional comparison. There would also be an increase in manual labour for weed control in organic vegetable growing. The assessment of this is outwith the scope of this study.

The organic rotation had a higher energy ratio than any of the conventional crops, even after the inclusion of dedicated fertility building crops and winter cover crops with no direct energy output.

Table 13. Comparison of whole-farm organic rotation and monocrop conventional production energy ratios.

	Overall Energy Ratio E1
Organic vegetable rotation	5.31
Conventional crops	
Leeks	3.11
Calabrese	0.81
Onions	2.41
Potatoes	2.15
Cabbage (savoy)	3.21
Carrots	4.80

Table 14. Conventional upland livestock - energy inputs, outputs and ratio.

	Area ha	Total Energy Input MJ	Indirect Energy MJ	Direct Energy MJ	Total Output MJ
Farm area	500				
Crop area	500				
Total energy (MJ)		445,398	322,408	122,990	489,747
Per unit area (MJ/ha)		891			979
Overall Energy Ratio E1		1.10			
Percentage		100	72	28	

Table 15. Organic upland livestock (as in OF0147) - energy inputs, outputs and ratio.

	Area ha	Total Energy Input MJ	Indirect Energy MJ	Direct Energy MJ	Total Output MJ
Farm area	500				
Crop area	500				
Total energy (MJ)		198,489	116,240	82,249	489,747
Per unit area (MJ/ha)		397			979
Overall Energy Ratio E1		2.47			
Percentage		100	59	41	

In upland livestock production, the greatest energy input is from the feeding of concentrates or cereals. In sheep, with organic production a greater proportion of the inputs is derived from grass. For suckler beef production, the main energy the main energy input is in silage production. The lower energy input into silage, and reduced concentrate feeding results in a reduction of energy inputs to the organic upland livestock system.

Similar stocking densities for organic and conventional production, as practised in OF0147, result in similar system outputs. This in turn results in a better energy ratio for the organic upland livestock system.

Table 16. Conventional dairy - energy inputs, outputs and ratio.

	Area ha	Total Energy Input MJ	Indirect Energy MJ	Direct Energy MJ	Total Output MJ
Farm area	26				
Crop area	26				
Total energy (MJ)		2,529,264	2,213,648	315,616	1,089,446
Per unit are (MJ/ha)		97,279			41,902
Overall Energy Ratio E1		0.43			
Percentage		100	88	12	

Table 17. Organic dairy (as in OF0146) - energy inputs, outputs and ratio.

	Area ha	Total Energy Input MJ	Indirect Energy	Direct Energy MJ	Total Output MJ
Farm area	50				
Crop area	50				
Total energy (MJ)		529,044	99,549	429,495	883,266
Per unit area (MJ/ha)		10,602			17,701
Overall Energy Ratio E1		1.67			
Percentage		100	19	81	

There is a marked reduction in indirect energy input in concentrate feed in the organic system. This is the main reason for the improved energy ratio of the organic system.

The direct energy used in milking and cooling of milk is the dominant energy use in organic production. In conventional production, concentrate feed is dominant.

4.4 Distribution energy costs

An overview of the main elements of energy cost for a range of supply scenarios was produced and is shown in Table 18. The energy per-load as supplied to supermarket distribution centre or wholesaler has been calculated for each scenario.

For imported produce, the energy cost of sea transport has been taken as 0.3 MJ/t km (Fluck 1992b, BUWAL, 1998). A delivery distance from the Channel ports to a packing centre in Birmingham (312 km) has been assumed.

Table 18. Transport energy from farm/grower to distribution centre.

	Scenario	Energy MJ	Energy MJ/t	Difference to scenario No. 1
1	Conventional or organic produce from a large unit.	**12000**	**600**	-
2	Organic produce to a co-operative shipping point.	**12567**	**628**	**+5%**
3	Organic produce transported direct to a nearby packing centre.	**7513**	**376**	**-37%**
4	Conventional or organic produce collected by nearby packer.	**6800**	**340**	**-43%**
5	Organic produce imported from northern Europe.	**17240**	**862**	**+44%**
6	Organic Produce Imported from southern Europe.	**54240**	**2712**	**+352%**
7	Local organic producer supplying a local wholesaler for local shops.	**6944**	**347**	**-42%**

In comparison to the base scenario for large scale conventional production with field trimming, smaller scale growing with delivery to a central co-operative shipping point for bulking loads uses 5% more energy (table 18). The effect of proximity to a packer in scenarios 3 and 4 reduced energy requirements by over 35%.

Importing from northern Europe had a 44% additional energy cost over UK large-scale conventional supply, and from southern Europe a 352% additional energy cost. However, produce imported from this distance and location is more likely to be glasshouse or Mediterranean crops, not field vegetables, so not directly comparable.

Local supply to a wholesaler for local shops, at 42% less than the baseline, did not show an advantage over the large producer with a nearby packer (scenarios 3 and 4).

Small vehicles with small payloads had a cost per tonne kilometre up to 15 times greater than a 20 t articulated container lorry. Loads of 1-3 t cost 2.5-4.79 MJ/t km in comparison to 1.0 MJ/t km for a 20 t lorry. Therefore, a number of small vehicle movements to make up a 20 t load could easily exceed the fuel use of a single longer trip.

5. CONCLUSIONS

A model has been developed to quantify the energy inputs into arable, field vegetable, and livestock enterprises for conventional and equivalent organic production systems. The model has been applied to a range of farming systems. The results presented in the report are from the input of average yield data; they are illustrative and not a definitive statement. The strength of the model is that it can be used to simulate many different management systems and yield expectations. The model can be readily updated for new base data, for different farming systems, or to test the effects of changes in inputs, outputs or livestock stocking rates.

5.1 Arable crops

Indirect energy input dominated conventional production, mainly in the form of fertilisers and pesticides. The absence of these large inputs resulted in better energy ratios from organic production for individual crops. When incorporated into crop rotations, this advantage was reduced in organic stockless systems by the presence of annual fertility building crops and winter cover crops with no direct outputs.

The use of fuel for drying grain was the highest direct energy input for conventional and organic combinable crops. Ambient air drying, which use 50 % of the direct energy of high temperature drying should be the preferred method. Scope to remove this energy input completely is limited due to the need to adequately dry grain before storage following wet harvest conditions.

Fertiliser was the dominant energy input in conventional cereal crops.

Transport energy cost for organic production was slightly higher due to fewer certificated organic grain facilities than conventional facilities, so resulting in longer average haulage distances.

There is little scope for substituting manual labour for energy inputs in arable organic production.

5.2 Vegetable crops

Indirect energy input dominated conventional production, mainly in the form of fertilisers and pesticides. In organic production, there were less obvious peaks of energy input. Indirect energy in harvesting onions and cabbage, and direct energy in onion drying and flame weeding of carrots were the largest inputs.

Mechanical weeding of organic crops involved less energy than herbicides did in conventional production.

Flame weeding may involve as much or more energy than herbicides.

The considerably increased manual labour in organic systems, particularly for weed control, is noted but is outwith the scope of this study. There may be scope to replace mechanical weed control by manual labour but this would be limited by the need for timeliness and the (increasing) difficulty in finding staff willing to do this job.

Transport energy inputs for organic vegetable crops are greater because of smaller production levels, smaller delivered loads and longer average distances to certificated organic packing facilities.

To reduce the energy cost of collection and distribution of organic vegetables, small-scale production should be grouped for transport to accredited packers. Further development of group marketing could be significant in improving energy efficiency.

Transport energy was increased by 352% when produce was imported from southern Europe, but only by 44% from northern Europe. Southern European imports are more likely to be of glasshouse or Mediterranean crops, so not entirely relevant in this exercise which considers field vegetables.

Local marketing of organic produce via wholesalers and local shops showed potential for reduction in energy cost of transport in comparison to conventional large-scale production. However, it was not better than delivery to, or collection by, a nearby packer. The latter two scenarios do not include the transport from distribution centre to retailers so local marketing, as may be expected, would result in the lowest overall energy costs in transport.

5.3 Livestock enterprises

Livestock enterprises generally have much lower energy ratios than crops, usually at around a value of 1. Dairy is the least efficient at only 0.46, meaning that less than half of the energy input is recovered in saleable output. In all cases, equivalent organic systems show a better energy ratio. For example, the organic dairy model has an energy ratio of 1.67.

Feeding home produced cereals could reduce the energy input into dairy production. This could offset the reduced energy output in the lower milk yields of organic systems.

Energy input levels for extensive conventional and organic grazing enterprises were more similar than arable or intensive livestock systems.

Fertiliser inputs were of little significance to upland sheep farming with most energy input as indirect energy in purchased forage and concentrates. The Energy ratios for hill sheep production of store lambs showed the smallest increase when an organic system of production was implemented.

For suckler beef production, the main energy inputs are into silage production.

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