Energy Inputs into the Average Arable/forage crop at Sheepdrove Organic Farm 2003/4

Report
October 2004

Sheepdrove Organic Farm

ELM FARM RESEARCH CENTRE

Executive Summary

- This report summarises the energy inputs and outputs for the arable/forage system of Sheepdrove Organic Farm 2003/4.
- The investigation was undertaken to explore the energy inputs into the arable/forage system.
- The first objective of the study was to analyse the on-farm energy inputs into the average of all crops per hectare and put figures to the inputs.
- The second objective was to identify significant inputs within the enterprise, to identify possible energy-saving techniques and identify potential alternative sources of energy.
- The arable farm manager was consulted and eight different rotations were found for the 2003/4 season.
- Activities for the crop growth season were identified and per hectare figures were calculated for each activity.
- The energy use through the season was analysed and presented graphically.
- The main uses of energy were identified as ploughing, combining and grain drying.
- Methods of reducing the energy input in ploughing and combine harvesting were identified such as maintenance and use of the most appropriate tractor for the job.
- Alternative fuels were considered. Bio-diesel was found to be the most viable alternative and a production cost of 27.52p/l was calculated. However since it has a lower energy content compared to diesel it would mean an overall increase in the fuel used. It would mean that the use of fossil fuels would be replaced by a renewable source of fuel and therefore the overall carbon footprint would be smaller.
- Ways to reduce the power input into the grain dryer were researched such as maintenance, operation method modifications, etc.
- Alternative methods of producing the power for the grain dryer were also investigated and it was found that a 6kW wind turbine was the best option.
- Finally, currently, the most fuel-efficient way to dry grain is using a fan-ventilated system using LPG.

Sheepdrove Organic Farm Arable/forage Enterprise Energy Cycle

Helen Bentley-Fox

1. Background

1.1. Currently the Sheepdrove Organic Farm (SOF) farm energy audit identifies leakages in the whole farm system and not each individual enterprise.

1.2. It has been suggested that the energy input into the arable enterprise can be reduced. In particular the tractor fossil fuel consumption and the grain drying operations are identified as the major inputs.

1.3. This study will provide a benchmark for the energy cycle in the arable/forage enterprise which can then be used to provide a model for any energy saving techniques that can be applied.

1.4. Energy savings will increase the profitability of the arable enterprise.

1.5. Alternative energy sources will reduce the carbon footprint of SOF. These do not necessarily increase or decrease the profitability of the arable crop but will assist in the aim of SOF to be a closed farm system.

1.6. This study is year specific to 2003/4 arable rotation.

2. Objectives

2.1. To analyse the on farm energy inputs into the average of all crops per hectare and put figures to the inputs.

2.2. To identify significant inputs within the enterprise, to identify possible energy saving techniques and potential alternative sources of energy.

3. Materials and Methods

3.1. The arable enterprise for 2003/4 season was analysed. The crops and their required operations were put into a flow chart and the rotations listed as eight potential rotation permutations.

3.2. The activities for management of each of these eight different options were recorded. Relevant information such as tractor make, model, hp, operation speed, etc., was then collected for each option.

3.3. The distance for each field from the Compost, Warren Farm and North Farm was calculated and the number of kilometres travelled for various operations was calculated.

3.4. The energy inputs for each crop were then calculated. The most recent data was used to take into account the improvements in engine technology and the changes to tractors such as air conditioning in cabs, etc. Where data gave a range, the median was taken. Where there was no data, similar operations were identified and the figures for that operation were used.

Where there were multiple operations at one time but only figures for individual operations were given then the two figures were added. If either operation was a range the lower value of one of the operations was taken to allow for less mass in the overall operation. Where the figures were found and how they were manipulated was put into the comments for each cell of the spreadsheet.

3.5. The data was then displayed on a graph for each rotation type and an overall rotation graph was produced.

3.6. Areas of high energy use were identified.

3.7. Using the internet and personal communication, energy saving options were explored and alternative sources of energy were looked at. If possible they were analysed and recommendations were given.

3.8. The indirect energy used was not considered. The indirect energy includes the energy used in the production of the equipment used, the energy needed to repair it over an average lifespan and the transportation of the equipment from the production plant to the farm. This would require a much more detailed study of the farm. The data needed for this has been collected and input onto the spreadsheet and could be calculated if required.

4. Results

4.1 The permutations are shown in the Appendix 1 but can best be shown by the following flow charts (Figures 4.1.1 and 4.1.2).

Figure 4.1.1: From field to harvest

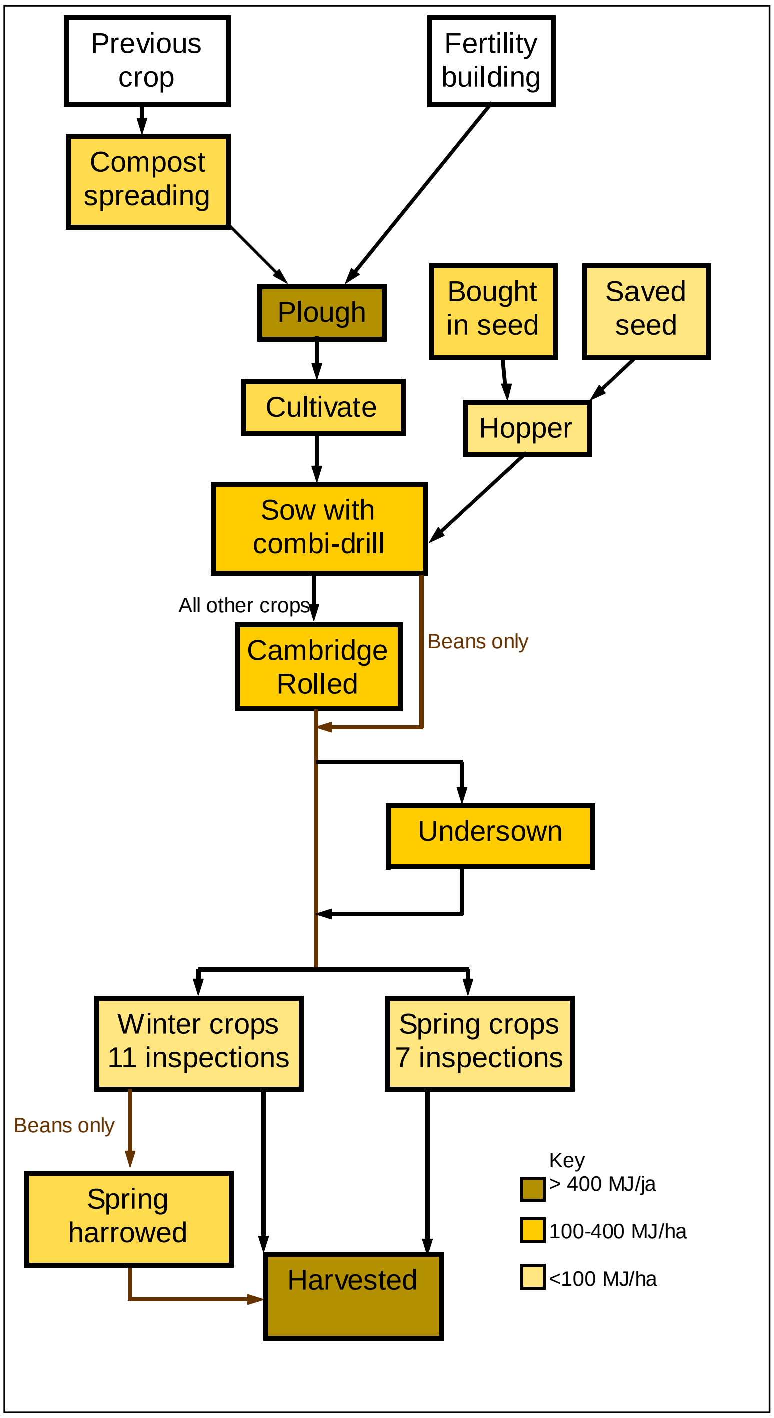
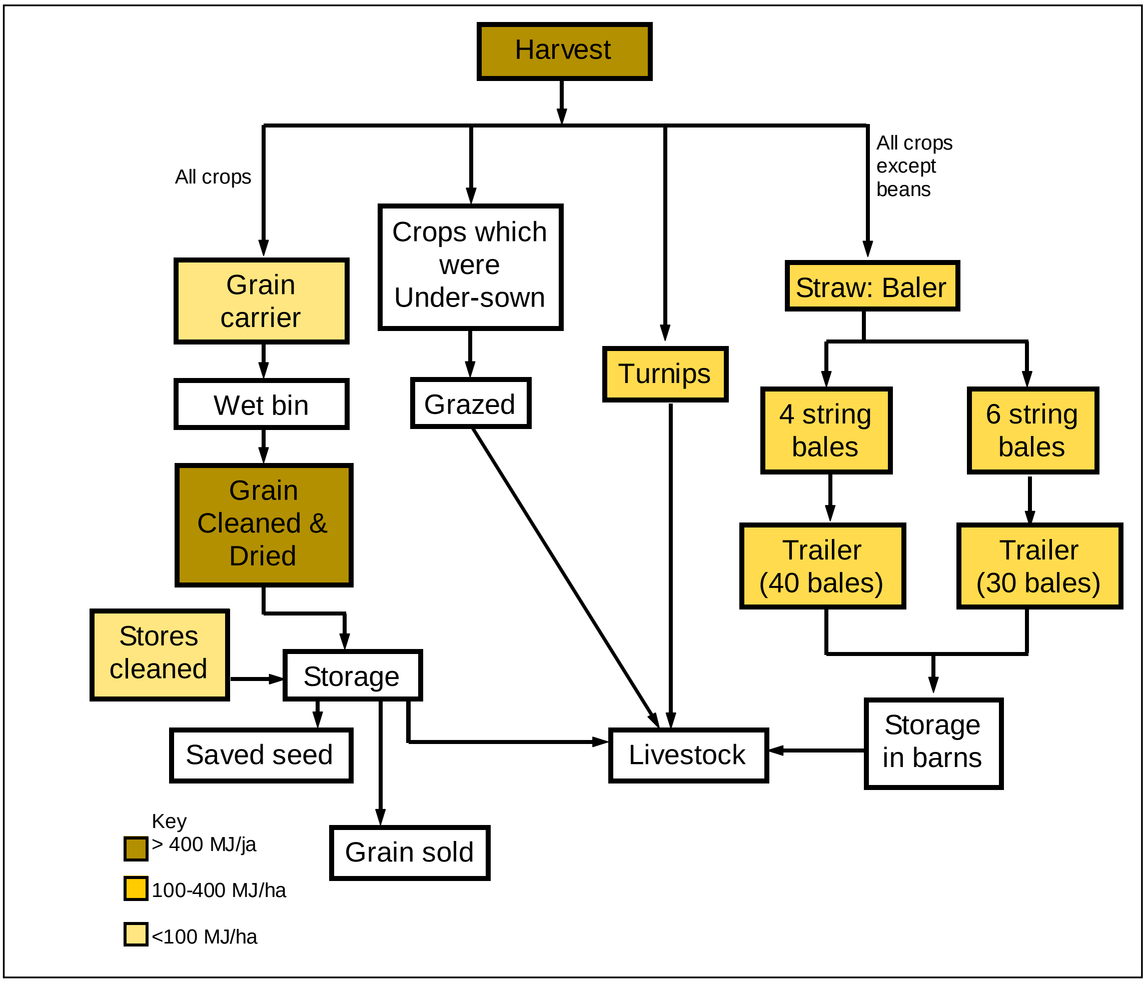


Figure 4.1.2: From harvest to finished product



This identified a number of differences in operations and thus energy inputs.

- The first is between crops that are first crops after a fertility-building period and the crops that have had a crop in the previous cropping period. The first crops after a fertility-building period do not require compost and were identified as **R1** and those after a previous crop were identified by **R2**.
- The second is between summer and winter crops. Both crops are inspected monthly but winter crops are in the ground for 11 months and summer crops only for 7 months. Therefore the letters **S** and **W** were used to identify between the two different season crops.
- The third is between crops that are under-sown and those that are not. The major input is the sowing of the under-sown crop. The letter **u** was used to identify those rotations that were under-sown.
- The fourth is between beans and other crops. Beans have a number of different activities, most notably: they are not Cambridge rolled, they are spring harrowed and they do not have straw as a product. These were identified by the letter **B**.

This gives at most twelve different options for rotations. Looking at the 2003/4 season and the previous season in 2002/3 eight different rotation options were identified and are shown in Table 1 below. The full list of activities is shown in Appendix 1.

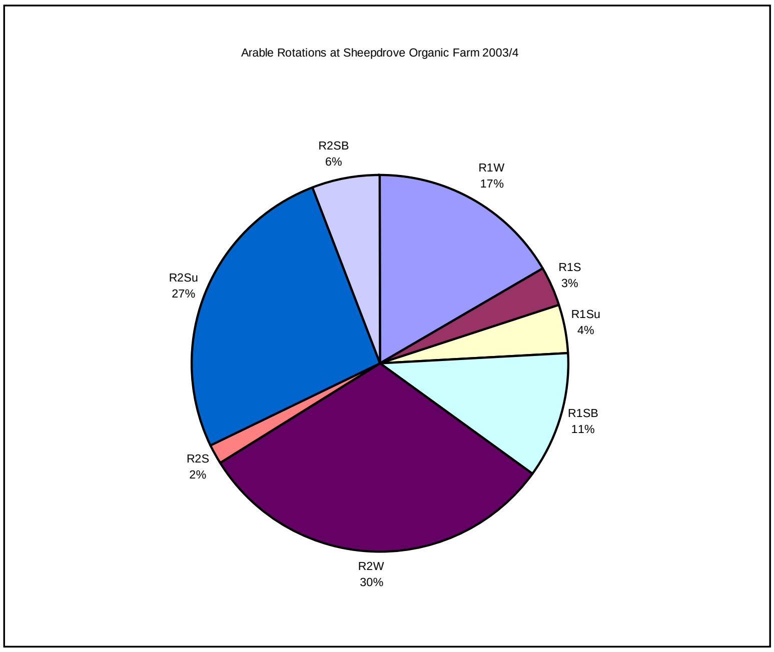
Table 1: The different rotations for the 2003/4 season

	Options							
	1st cereal after ley				**2nd and subsequent arable**			
	Winter cropping	Spring cropping			Winter crop	Spring crop		
Rotation	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**
Previous crop 2002/3	Conversion fertility building, grass clover ley				Previous crops include forage, WW, SB, S Beans			
Crops 2003/4	WW	SW	SB	SB	WW	SB	SO, SW, SB	S Beans
Undersown	N/A	N/A	RC	N/A	N/A	RC	WC, RC, Peas	N/A

Key
WW – winter wheat
SW – spring wheat
SB – spring barley
SO – spring oats
WC – white clover
RC – red clover
SB – spring beans

4.2 The number of hectares of each rotation type was calculated and is shown in the Figure 2.

Figure 2: The Different Rotation areas for 2003/4 shown as a percentage of the area of Sheepdrove Organic Farm



4.3 Energy used (MJ), for each of the activities in Figures 4.1.1 and 4.1.2, was calculated. The figures for this were drawn from information in three main papers - Audsley (1997), Witney (1998) and Bridges and Smith (1979) using the most recent figures available and the energy constant 47.2 MJ/l of fuel. Where a range was offered the median was used.

4.4 If the activity was a combination of the two then the mid-range of one activity was used and the lower range of the second was used since there is less mass to be pulled (ie only one tractor) and therefore less energy is required. These estimates and how they were made are described for each figure in the comments for the cell in the spreadsheet. The energy for the following activities were not calculated: grain moisture testing, grain cooling and cleaning the storage area due to limitations of the researcher and time.

4.5 For grain drying, the quantity of fuel used and the number of kWh of electricity used for the 2004 season had been recorded and both were converted to MJ. The spreadsheet for R1W is shown in Appendix 2. The summary spreadsheet for the eight different rotations is shown below in figure 4.5.1.

Crop Management	MJ/ha for each activity against the Rotation type								Average
Rotation Type	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**	**MJ/ha**
Soil improvements	0.00	0.00	0.00	0.00	377.60	377.60	377.60	377.60	188.80
Ploughing	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00
Cultivation	236.00	236.00	236.00	236.00	236.00	236.00	236.00	236.00	236.00
Seed transport	188.80	188.80	188.80	188.80	188.80	188.80	188.80	188.80	188.80
Sowing	165.20	165.20	165.20	165.20	165.20	165.20	165.20	165.20	165.20
Rolling	188.80	188.80	188.80	0.00	188.80	188.80	188.80	0.00	141.60
Undersowing	0.00	0.00	708.00	0.00	0.00	0.00	708.00	0.00	177.00
Inspections	9.54	7.64	7.52	40.95	7.73	27.19	27.19	6.67	16.80
Combine	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00	1,534.00
Post harvest cultivation	236.00	236.00	236.00	236.00	236.00	236.00	236.00	236.00	236.00
Grain transport	188.80	188.80	188.80	188.80	188.80	188.80	188.80	188.80	188.80
Clean storage area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test sample for moisture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dryer	972.23	972.23	972.23	972.23	972.23	972.23	972.23	972.23	972.23
Cooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baling	377.60	377.60	377.60	0.00	377.60	377.60	377.60	0.00	283.20
Bale transport	424.80	424.80	424.80	0.00	424.80	424.80	424.80	0.00	318.60
Loading and unloading	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grazed or silage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total energy used per hectare (MJ)	6,056	6,054	6,762	5,096	6,432	6,451	7,159	5,439	6,181

Figure 4.5.1: MJ/ha energy used for activities in each rotation type for SOF

NB: Some areas figures have not been calculated due to lack of availability of suitable conversion figures, for example, cleaning the storage area and cooling of the grain.

4.6 Using these figures it is now possible to compare the different rotations and see where the main inputs of power take place. First comparison is between summer and winter rotation1 crops i.e. R1W and R1S.

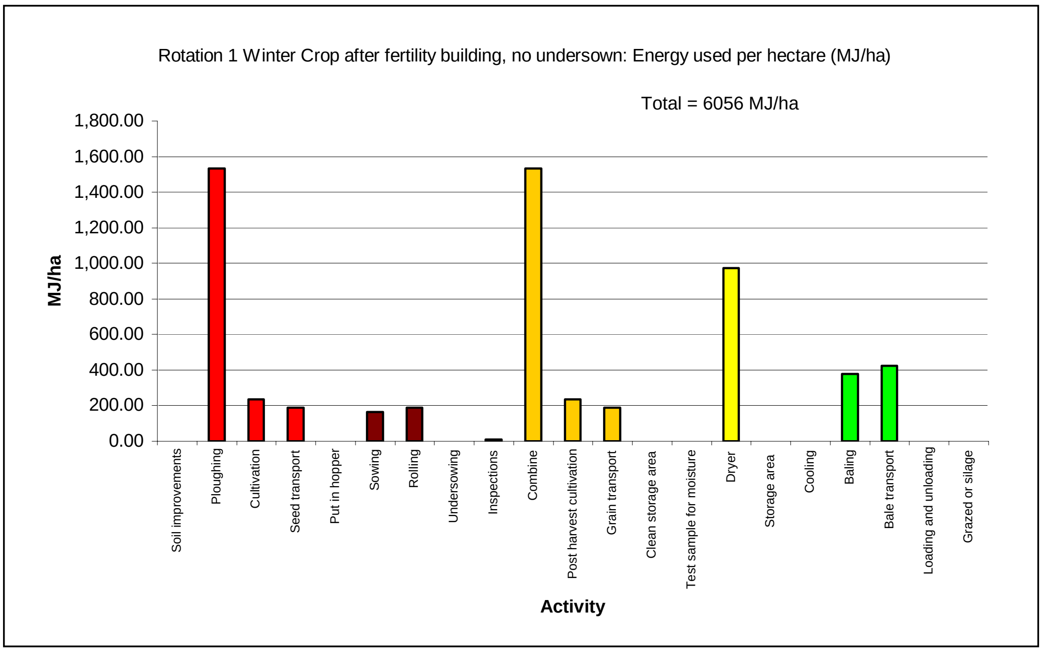


Figure 4.6.1: Winter crop after fertility building

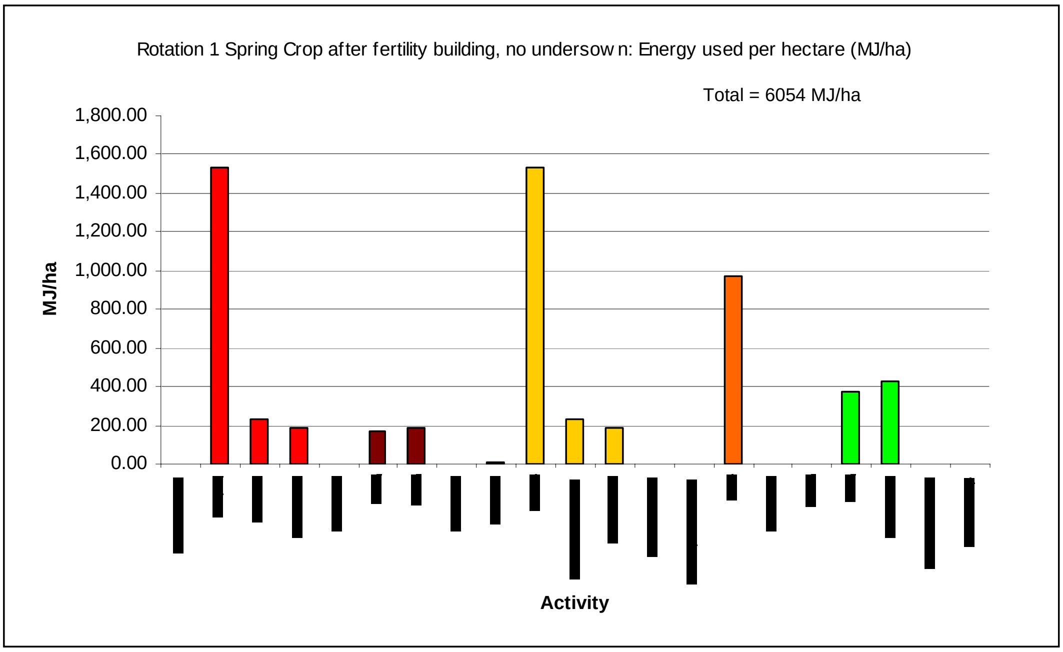


Figure 4.6.2: Spring crop after fertility building

Figures 4.6.1 and 4.6.2 show the main energy inputs as ploughing, combining and drying of the grain. These activities are carried out in all the different rotations and are therefore the most significant inputs. Between winter and spring crops there is very little difference between the energy inputs per hectare.

The difference in activities is the inspections, but this is negligible when you compare the energy used in inspections to activities such as ploughing, combining or drying.

4.7 The next comparison is between spring crops after fertility building and whether or not it is under-sown.

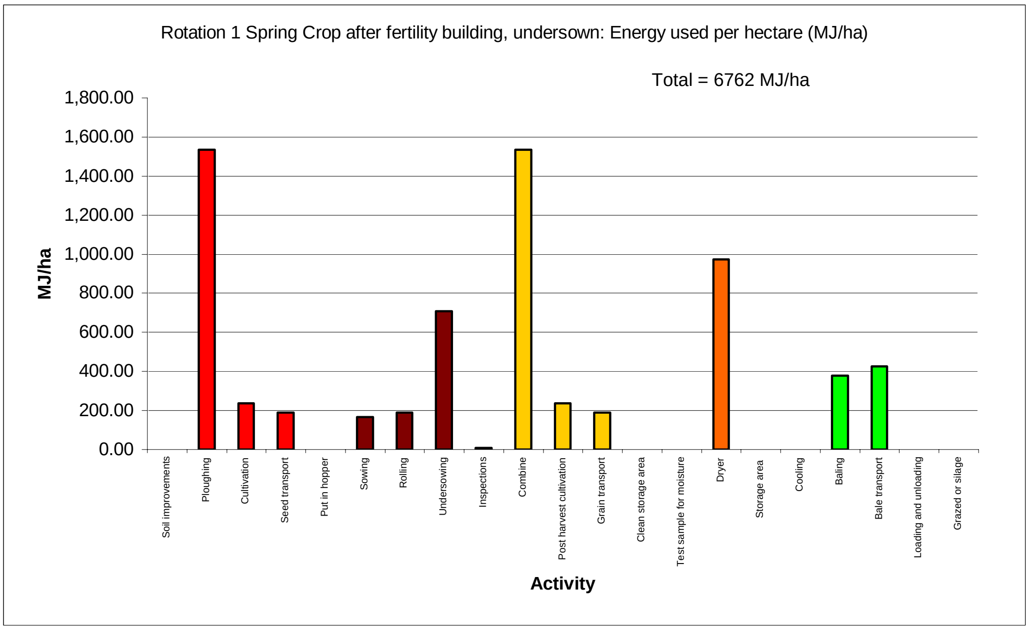


Figure 4.6.3: Under-sown Spring crop after fertility building.

When comparing figure 4.6.3 and figure 4.6.2 one can see that the main difference is the energy used in under-sowing the crop. Whilst not as high as ploughing, combining or drying it is still one of the major energy inputs for this rotation type.

4.8 Comparing the operations for spring beans it is can be noted that ploughing, harvesting and grain drying are still the major energy inputs. See Figure 4.6.2 above for other spring crops and compare with figure 4.6.4 below shows beans.

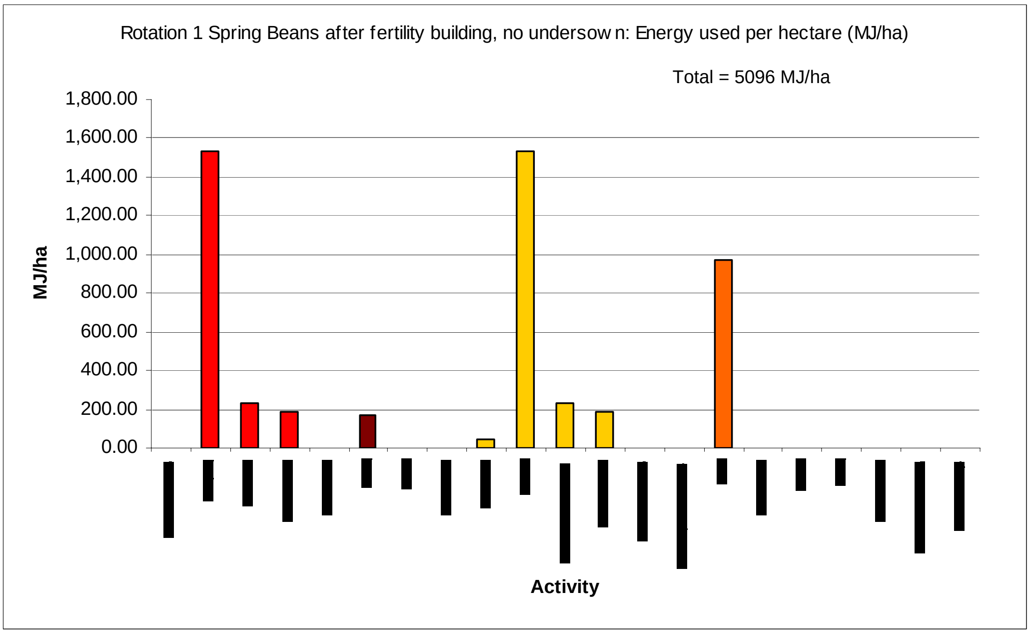


Figure 4.6.4: Spring beans after fertility building.

The main differences are that beans are not rolled and there is no straw to be baled. The inspections per hectare are distorted since there are a number of small fields a long distance from Warren farm. Since this is calculated as a single trip to each field it distorts the figures.

4.7. Comparison of first rotation crops and subsequent crops.

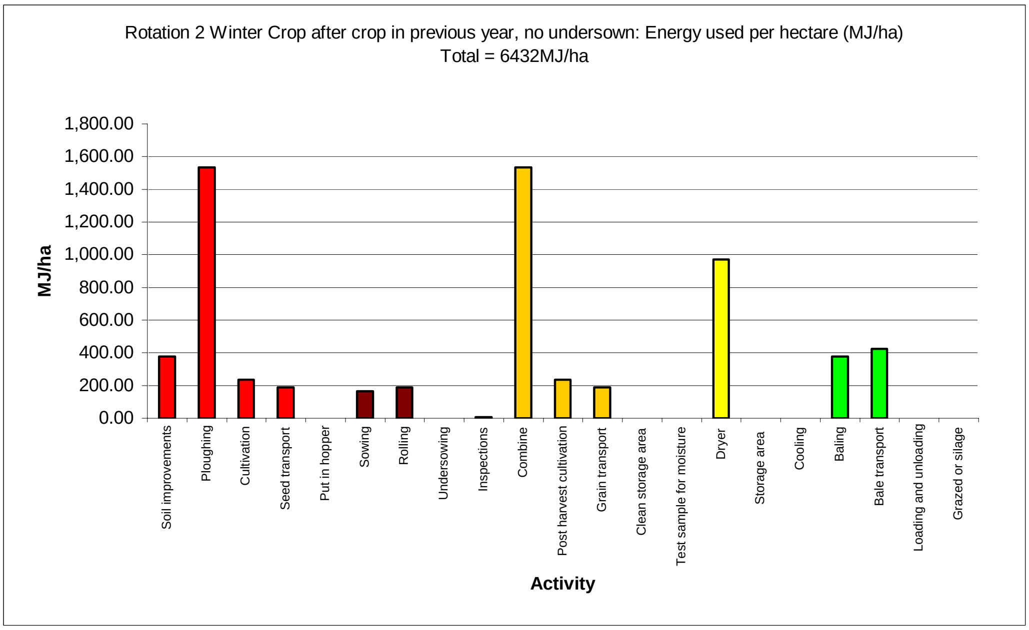


Figure 4.7.1: Winter crop after crop in previous year

The main difference comparing Figure 4.6.1 and Figure 4.7.1 is that energy is required for soil improvements. The energy needed to do this is not as high as the three main activities but is noticeable and should therefore be taken into account.

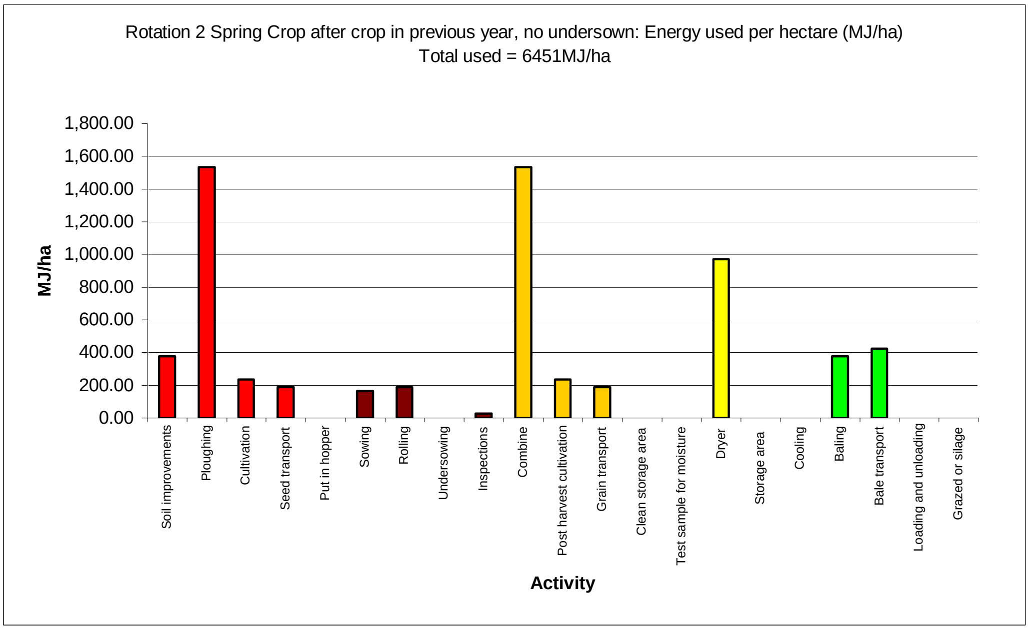


Figure 4.7.2: Spring crop after crop in previous season

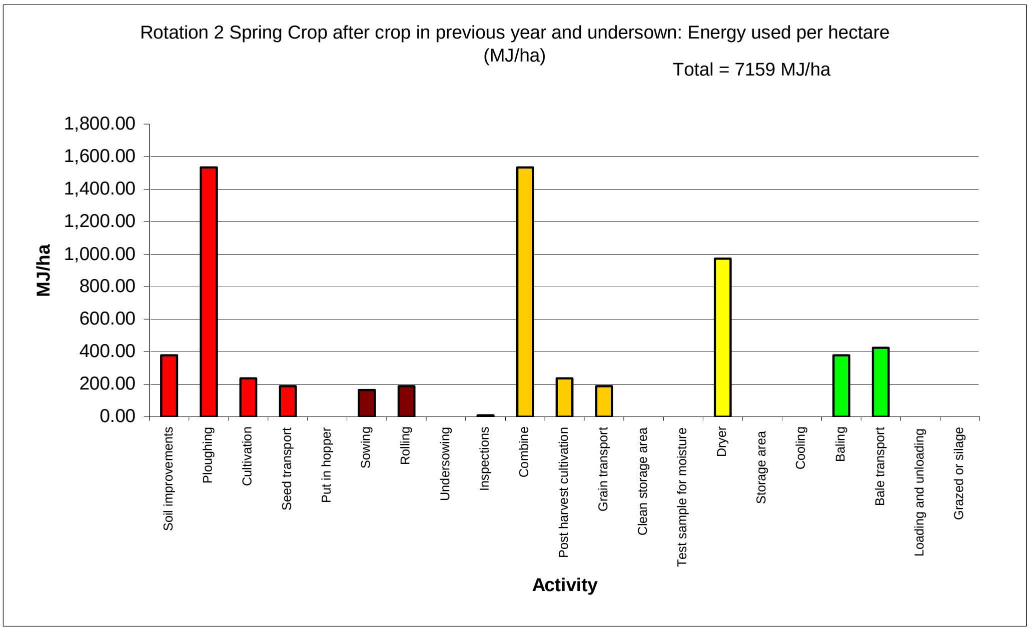


Figure 4.7.3 Under-sown spring crop after crop in previous season

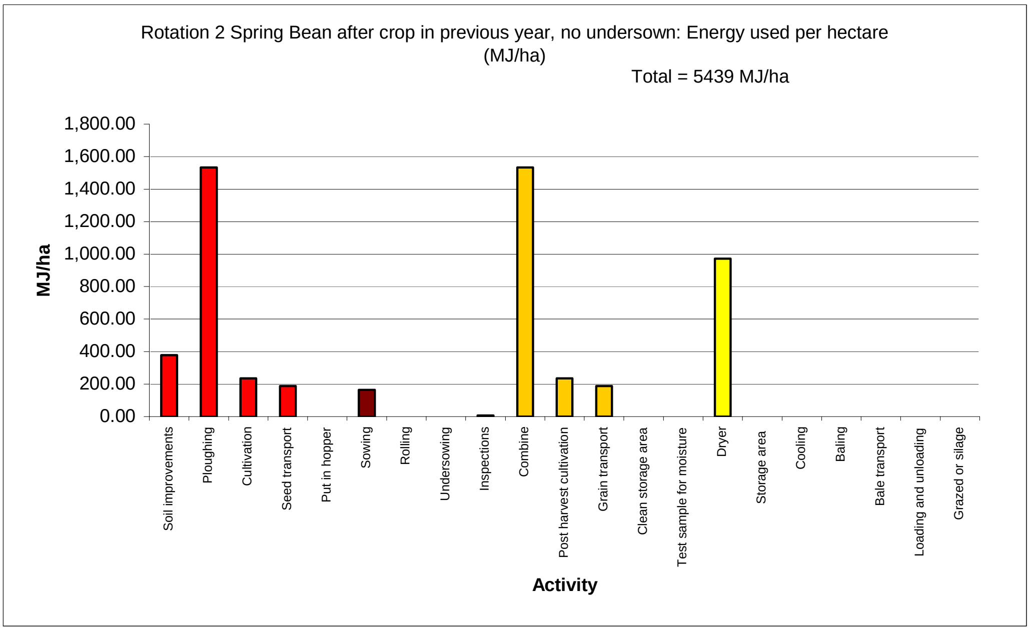


Figure 4.7.4: Spring bean after crop in previous year

Figures 4.7.2 to 4.7.4 show similarities to the differences required for that crop type in rotation 1. They all however, require soil improvements in the form of compost spreading.

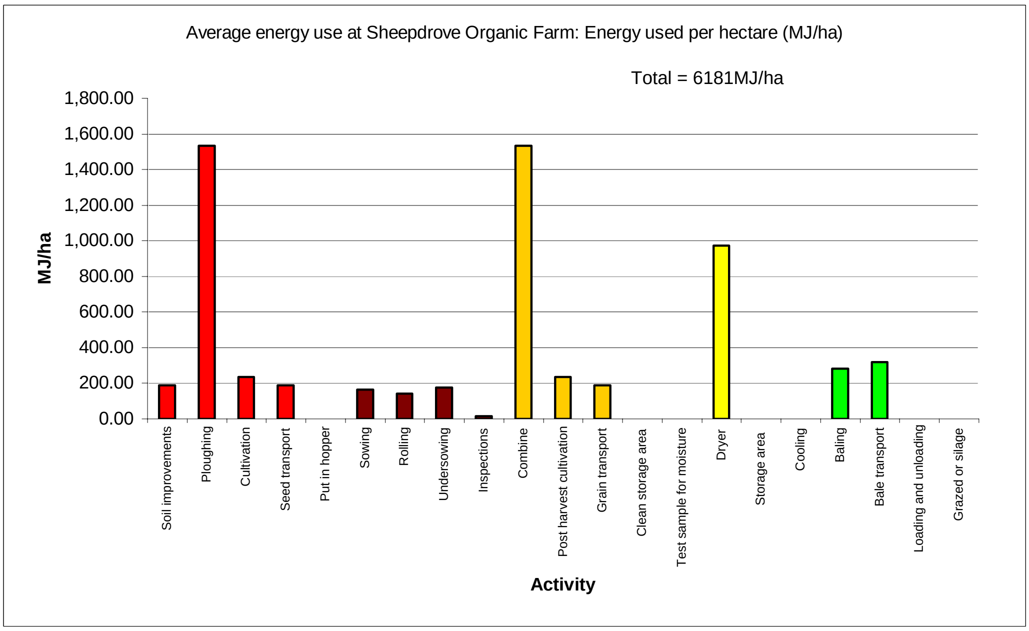


Figure 4.7.5 : Average energy use for arable crops.

Figure 4.7.5 shows the average energy use per hectare for growing a crop at Sheepdrove Organic Farm during the 2003/4 season. It identifies ploughing, combining and drying the grain as the main energy inputs into the system. Ploughing and combining use fossil fuels whereas the dryer uses both electricity and fossil fuel -approximately, the energy equivalent of 130 litres of diesel per hectare.

5 Conclusions & Recommendations

5.1 There are three main inputs of energy into the crop rotations. Ploughing, combining and drying the grain. The first two require a closer look at the vehicle operations. The third requires a closer look at the grain drying process and the inputs required.

5.2 The tractors and combine harvester both require the use of fossil fuel i.e. diesel. There are two issues to discuss: firstly, reducing fuel use, secondly replacing the fossil fuel with an alternative fuel from a renewable source. The second option whilst not reducing the energy input will actually reduce the carbon footprint of SOF.

5.3 Reduction in the amount of fossil fuel used. We need to consider the following

5.3.1 Vehicle and tractor use. An immediate saving could be made by reducing fuel-use through regular maintenance, use of appropriate vehicle for the task in hand and good driving techniques.

For example the Carbon Trust (undated) states that if "*tyre pressure is low by 2 PSI it can increase fuel consumption by 3% and a misalignment of 1^o in the steering increases tyre wear and fuel consumption by a further 4%*."

Further key points and recommendations are described by the Carbon Trust document "Energy saving guide for agriculture and horticulture" - undated.

Figure: 5.3.1.1: Use less energy: Tractors and vehicles.

Regular checks	*Carry out regular checks of tyre pressure, lubricant levels, etc to ensure tractors and vehicles continue to operate in optimum condition*
Maintenance	Regular servicing will save money and reduce exhaust emissions. *Set up a schedule for servicing all tractors and road vehicles*
Driver training	Poor driving techniques have been shown to increase fuel consumption by 20%. *Set up a driver training programme so all staff understand how to drive tractors and machines effectively*
Machine allocation	Allocating machines to the most appropriate task is the best way of achieving efficient fuel use. *Draw up a schedule of tasks listing the most appropriate tractor and equipment combinations*.
Tractor set-up	Ballast levels and the correct tyre pressures ensure that draught operations are carried out effectively. *Ballast should be removed and tyre pressures readjusted when the tractor is not being used for draught work. Draw up a schedule of ballast and tyre pressures for tractors and draught implement combinations*.

The first two have been in place since the new arable manager was employed. However, throughout the field operations, the larger two tractors on the farm are used i.e. the John Deere 7820 and 6920. The speed of the operation and energy efficiency of this requires further study and the most appropriate tractor hp for the job in hand should be identified.

In Audsley (2004, (p9)) a comparison of tractor – plough work rates and performance are looked at. It was shown that for a 4WD tractor in light soil the most fuel-efficient was a tractor using 60kW of power, compared to 120kW. It of course took longer but there was a difference of 5 l/ha fuel used. In a heavy soil the same difference in engines produced a 10 l/ha difference.

5.3.2 Cultivation methods should be looked at for example minimal tillage or direct drilling. Although organic agriculture relies on ploughing to reduce weed problems, it may be possible to use some of these methods at different times within the rotation.

5.4 Once energy has been reduced, replacing diesel with an alternative fuel. There are a number of fuel options available: methanol, ethanol, bio-diesel and LPG. However, with current technology and the power required we can only really consider bio-diesel for the arable field operations. There are three methods of providing bio-diesel for the farm.

5.4.1 Purchasing bio-diesel. Bio-diesel is currently being sold at around 80p/l. This includes duty and it is currently economically unviable.

5.4.2 Making the bio-diesel from an oil crop. The two possible options are oil seed rape and dwarf sunflowers. Both these crops give an oil of a suitable viscosity to produce bio-diesel. However, the next issue is that neither of these two crops is grown in sufficient quantities in the organic system in the UK. Oil seed rape is seen as a problem crop in the organic system and dwarf sunflowers oil is worth around 30ppl. This makes growing their own oil currently unviable

5.4.3 Making the bio-diesel from used vegetable oil. A suitable large source would need to be found and unfortunately the bio-diesel would still be subject to duty.

Figure 5.4.1.3: Comparison between bio-diesel and red diesel

	Bio-diesel (p/l)	**Red Diesel (p/l)**
Waste oil	10	0
Production cost (incl. labour and electricity)	13.3	0
Duty	4.22	0
Total cost for fuel	**27.52**	**24.95**

Based on figures from Haynes, T, MEA, pers comm. 2004 and August 2004 accounts SOF

Additional costs and factors that should be noted:

a. Capital investment £4995 for 100,000 l/annum system (Haynes,T, *pers comm*.)
b. Bio-diesel has a lower calorific value of 36 MJ/l compared to diesel 47.2 MJ/l and so annual consumption of red diesel is currently around 73,000 litres.

SOF would require almost 97,000 l. So, converting to bio-diesel would actually increase the energy consumption of SOF. See Figure 5.4.1.4 below.

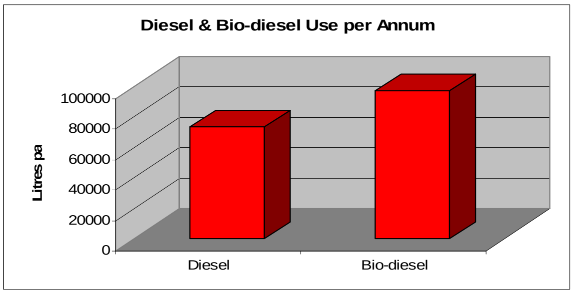


Figure 5.4.1.4: Sheepdrove Organic Farm 2002/3 Red Diesel consumption and potential bio-diesel consumption

5.5 The continuous flow grain dryer installed at North Farm uses a combination of diesel and electricity. The diesel could be replaced by bio-diesel if SOF is wishing to reduce their carbon footprint – this option is described above.

The grain dryer operations are as follows:

Figure 1:Looking up at the air Intake for Grain dryer

Figure 2: Air exhaust from grain dryer

Figure 3: Cleaner for dry grain

Figure 4: Elevator tubes taking grain from one piece of equipment to another

5.5.1 Ways to ensure efficient use of the energy consumed by the current grain dryer. These are outlined in “Energy Saving guide for agriculture and horticulture”, produced by the Carbon Trust, undated:

Fans	As the primer mover of any drying and cooling system, it is essential that the fan is in good working order and well maintained. *Check for corrosion and damage, clean the blades thoroughly and have the fan performance tested to check that it reaches the specified speed, output, etc*.
Air inlet & exhaust vents	Inadequate or badly designed and constructed air inlets and outlets can restrict airflow in and out of the dryer. *Check that the inlet and exhaust vents are of suitable size and clear any obstructions to airflow*.
Heaters	Inoperable or inadequate heaters or dehumidifiers can prolong drying times and increase costs. *Put a maintenance plan in place to make sure that heaters operate to optimum efficiency.*
Controls	Efficient operation of dryers can be achieved by using automatic humidity control of fans and heaters. *Use humidity-based controls and check the calibration of sensors at least annually*.
Air ducts	A leaky main air duct can lead to air loss of at least 10%. This inevitably leads to slower drying. *Inspect ducts and repair as necessary*
Ventilated floor & lateral ducts	Ventilated floor and lateral ducts are frequently damaged from broken grains, soil, et. *Clean and repair lateral ducts and floors to avoid uneven airflow and excessive back pressure.*
Operating strategy	The efficiency of a dryer is highest during periods of warm weather. *Drive the dryer hard during the harvest period to aim to finish as soon as possible after completion of cutting*
Lighting	Use discharge light such as high-pressure sodium for store illumination. *To comply with crop assurance schemes all lamps should be equipped with shatterproof covers*.

Currently, B&K conduct a pre-season check on the whole system looking at some of these items. It is recommended that the farm manager ensures that all relevant pre-season checks take place and that operators are aware of the efficiency operations.

5.5.2 Reusing heat lost through the exhaust fan. This air is saturated with water and in order for it to be reused it would have to have the water removed. This can be done with a heat pump dehumidifier. This is feasible but since the grain dryer works at relatively low temperatures the economics of this recovery is difficult to justify. *Pers comm. Andrew Kneeshaw. Farm Energy Centre.*

5.5.3 Alternative sources of energy could come from the following options: biomass (including anaerobic digestion and burning – possible link to reed bed system and digester requires further investigation), ground heat source pump wind energy or photovoltaic solar panels.

5.5.4 We can eliminate photovoltaic since the energy requirement is too high and weather dependant.

5.5.5 We can also eliminate biomass and ground heat source pumps since the grain dryer is only used for a few weeks each year and it spends much time idle, and the capital outlay is high reducing the cost efficiency of installing such products.

5.5.6 Installation of a wind turbine. The excess energy produced at times outside of harvest time could be sold to an electricity supplier.

Figure 5.5.6: Wind turbine at Brill School. Photograph courtesy of TV Energy

For this type of enterprise we would need a 6kWh turbine at 11 to 15m high. With an average wind speed of 5m/s it can produce 11-12000kWh of electricity a year. The complete installation of this type of wind turbine could cost around £21000.

TV Energy are working with electricity suppliers who are happy to work with this system.

A matter for further consideration is that in a couple of years it may be possible to offset the cost of installation against tax through the Enhanced Capital Allowance Scheme.

SOF is not eligible for a Clear Skies Grant on this unless it is a not for profit organisation.

Pers comm. Ian Bacon, TV Energy.

Planning permission is required. There is a current application just outside of Lambourn which would be a good example to follow to see how it progresses.

5.5.7 A final option is to replace the grain dryer altogether. The most energy efficient dryer at present is a fan-ventilated system using LPG. This offers a 95% combustion heat efficiency. Although the capital cost is high and the primary fuel is also electricity, feasibility of this option may be looked at in conjunction with the wind turbine option. *Pers comm. Andrew Kneeshaw, Farm Energy Centre.*

5.5.8 Grain store cooling. The energy used here has not been calculated, however, it is possible to use a dehumidifier which will reduce the temperature at which the grain goes to store. This would make the stored grain more stable. The overall efficiency of this should be looked into further.

5.6 Overall recommendations. The efficiency of each option raised should be discussed with an advisor such as TV Energy or Farm Energy Centre to get a full idea of the feasibility of each option.

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References

Name	**Date**	**Title of publication**	**Publisher/Journal**	**Employer and contact details**
Haynes, T	2004			Marches Energy Agency, Tristan@mea.org
Kneeshaw, A	2004			Farm Energy Centre, 0247 6696512
Bacon, I	2004			TV Energy, ian.bacon@tvenergy.org
The Carbon Trust	Undated	Energy saving guide for Agriculture and horticulture	The Carbon Trust	www.thecarbontrust.co.uk
Bridges, TC & Smith EM	1979	A method for determining the total energy input for agricultural practices	Transactions of the ASAE	
Audsley, E	2004	Food and agriculture, mechanisation and automation, technology and power, expenditure and returns	Unpublished	Silsoe Research Institute

Appendix 1

Options

	1st cereal after ley				2nd and subsequent arable			
	Winter	Spring cropping			Winter crop	Spring crop		
Rotation	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**
Previous crop 2002/3	Conversion fertility building, grass clover ley				Previous crops include forage, WW, SB, S Beans			
Crops 2003/4	WW	SW	SB	S Beans	WW	SB	SO, SW,	S Beans
Undersown	N/A	N/A	RC	N/A	N/A	RC	WC, RC,	N/A

No.of ha 2004

Crop Management

Seed bed preparation	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**
Soil improvements	Not necessary				Compost spread 25 tonnes/ha			
Weed control	Not unless necessary							
Ploughing	Plough 7 to 8 inches (20cm)							
Cultivation	Vadestat carrier to 2 inches (5cm)							

Sowing	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**
Seed transport	75% own saved seed, 25% bought in							
Put in hopper	Own seed carried in bucket (1t) or in bags bought in (2t) at a time driven to field							
Sowing	Vadestat (combi) disk drill sown at depth of 2cm, usually at a rate of 200kg/ha							
Rolling	Cambridge rolled			Not rolled	Cambridge rolled			Not rolled

Undersowing	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**
Undersowing	N/A		Grass harrow with fan blower blowing seed.	N/A			Grass harrow with fan blower blowing seed.	N/A

Cultivation during season	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**
Inspections	11 visits during season with Toyota Hilux	7 visits during season with Toyota Hilux			11 visits	7 visits		
Weed & pest control	None unless necessary			Spring harrowed	None unless necessary			Spring harrowed

Harvesting	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**		**R2Su**	**R2SB**
Combine	Claas Lexion							
Post harvest cultivation	Raking							

Post harvesting	**R1W**	**R1S**	**R1Su**	**R1SB**	**R2W**	**R2S**	**R2Su**	**R2SB**
1. Grain								
Grain transport	Grain trailer runs alongside combine and then to North Farm to unload							
Clean storage area	Sand blasted with air compressor. Takes 40 litres of fuel and sand and 1 day. Contractors do work.							
Test sample for moisture	20g of seed ground by hand. Hand held moisture calibrator.							
Dryer	Elevator fed from wet bin, through drier until dry, cleans and then to storage area.							
Vermin contol	Only if necessary							
Storage area	Concrete walls errected to separate the crops							
Cooling	Cool grain by blowing cold air through							
2. Straw								
Baling	Baled by contractor with either 4 string or 6 string (8ft long)			N/A	Baled by contractor with either 4 string or 6 string (8ft long)			N/A
Bale transport	40 4 string or 30 6 string loaded onto trailer with loader.			N/A	40 4 string or 30 6 string loaded onto trailer with loader.			N/A
Loading and unloading	Loader follows trailer from field to barn and back			N/A	Loader follows trailer from field to barn and back			N/A
3. Undersown								
Grazed or silage	N/A	N/A	Grazed	N/A	N/A	Grazed	Grazed	N/a

Appendix 2

R1W Energy spreadsheet

Crop Management		fuel use(l/ha)	Figs from	Energy used per hectare (MJ/ha)	Electricity used kWh	Electricity used per hectare (kWh/ha)	Electricity energy used per hectare (MJ/ha)	Fuel used in grain drying (l)	Fuel used per hectare of grain (l/ha)	Energy fuel used per ha of grain (MJ/ha)
Soil improvements	Not necessary									
Ploughing	Plough 7 to 8 inches (20cm)	32.5	est Audsley 1997	1,534.00						
Cultivation	Vadestat carrier to 2 inches (5cm)	5	Audsley 1997	236.00						
Seed transport	75% own saved seed, 25% bought in	4	est Audsley 1997	188.80						
Put in hopper	Own seed carried in bucket (1t) or in bags bought in (2t) at a time driven to field									
Sowing	Vadestat (combi) disk drill sown at depth of 2cm, usually at a rate of 200kg/ha	3.5	est Audsley 1997	165.20						
Rolling	Cambridge rolled	4	witney 1988	188.80						
Undersowing	N/A									
Inspections	11 visits during season with Toyota Hilux		Channel 4 road test of hilux = high 20s mpg	9.54						
Combine	Claas Lexion	32.5	est Audsley 1997	1,534.00						
Post harvest cultivation	Raking	5	Audsley 1997	236.00						
Grain transport	Grain trailer runs alongside combine and then to North Farm to unload	4	Audsley 1997	188.80						
Clean storage area	Sand blasted with air compressor. Takes 40 litres of fuel and sand and 1 day. Contractors do work.									
Test sample for moisture	20g of seed ground by hand. Hand held moisture calibrator.									
Dryer	Elevator fed from wet bin, through drier until dry, cleans and then to storage area.			972.23	10,000.00	27.25	7.57	7500	20.43763795	964.6565114
Storage area	Concrete walls errected to separate the crops									
Cooling	Cool grain by blowing cold air through									
Baling	Baled by contractor with either 4 string or 6 string (8ft long)	8	est Audsley 1997	377.60						
Bale transport	40 4 string or 30 6 string loaded onto trailer with loader.	9	est Audsley 1997	424.80						
Loading and unloading	Loader follows trailer from field to barn and back									
Grazed or silage	N/A									

Total energy used per hectare (MJ)			6,055.77