Project title:	Energy efficiency case studies for field vegetables enterprises
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Project leader:	Chris Plackett, FEC Services Ltd
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Location of project:	FEC Services Ltd, Stoneleigh, Warwickshire & various commercial field vegetable production sites
Industry Representative:	John Sedgwick, Stewarts of Tayside
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Date project completed (or expected completion date):	4th March 2011

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Chris Plackett
Commercial Director
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Signature Date 4th March 20011

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CONTENTS

GROWER SUMMARY

Headline

Farm enterprises can make energy savings of 10 to 15% with little or no capital investment.

Background

Increasing energy prices, new energy legislation and customer demand for produce with a low carbon footprint are all factors which are contributing to increased energy costs for growers of field vegetables.

Whilst energy costs currently only account for between 3% and 7% of the current farm gate value of vegetable crops grown in the UK, any increase in energy prices in the future will reduce margins and potentially threaten the viability of production. Even the most modest predictions are suggesting energy price increases of 75% or more by 2030, so clearly growers need to take action to reduce the impact of these increases on their business.

So that they can implement practical and cost effective energy saving technologies, growers need impartial information about the effectiveness of the various options available to them. This project uses the information gathered from six field vegetable producers to assess the current standards of energy management and energy efficiency in the sector. The findings are also used to provide guidance on the best ways that growers can make improvements and implement commercially proven energy saving technologies.

Summary of the results and main conclusions

Energy assessments were carried out on six representative businesses covering the major outputs from the UK field vegetables sector. These assessments established the current levels of energy use for each site and determined the scope for making energy savings.

The findings from the surveys have determined the current standards of energy management and energy efficiency of the participating sites. The information gathered has also been used to identify where energy saving measures can be used to reduce energy consumption and cost.

Despite the varied nature of the businesses that were surveyed, several universal energy processes were identified. These were:

- Produce cooling – including ventilation, air movement, refrigeration etc. for short, medium and long term storage and in packhouses
- Tractors and vehicles – including cultivations, chemical / fertiliser application, harvesting and transport.
- Irrigation
- Lighting – this is of particular importance in the packhouse, cold store / crop store and in employee facilities / accommodation

All growers should use these areas as the focus for their energy saving efforts as they present the best opportunities for implementing cost effective technologies and securing reliable savings.

Financial Benefits

It is believed that producers of field vegetables in the UK currently consume 1,850 GWh/year of energy, which at current energy prices has a value of around £50 million/year. This project suggests that growers can easily reduce the current consumption levels by 10 to 15%. If these levels of savings are achieved by all growers, the sector will save in excess of £5 million /year.

For the businesses assessed in this project the average energy consumption was 4,500,000 kWh/ year costing £296,600. If the predicted savings are achieved, these sites will each save an average of £44,500/ year.

Action Points for Growers

The following guidelines should be used as the starting point for implementing energy efficiency on a field vegetable enterprise:

Monitor your energy use and track consumption against production / output levels. Where appropriate break down to individual fuel types and / or end uses (e.g. kWh/tonne stored, kWh/mm irrigation water applied etc). Use the data you collect to set realistic but challenging improvement targets for the future.

Implement a simple turn it off / close it / turn it down campaign. Communicate the importance of energy saving to all your staff.

Check the insulation and sealing of your crop stores / cold rooms etc. Repair any damaged insulation, door seals etc and close of gaps around pipe or cable entry points etc. If current insulation standards do not achieve the current minimum requirements (typically a U value of between 0.3 and 0.4 $W/m^2/^oC$) install some upgraded insulation.

Check, clean and maintain all fans, ducts, air distribution components etc.

Calibrate control sensors, place sensors in the best position for taking accurate readings and check the function of store controls.

Maintain refrigeration equipment regularly; pay particular attention to refrigerant levels and the airflow over the evaporator and condenser coils. When making refrigeration equipment purchases ensure that new equipment uses advanced capacity control technologies such as variable speed drive compressors, electronic expansion valves and floating heat pressure control.

Clean lights regularly (including both the bulb and the fitting). When repairing or upgrading lights consider upgrading to the energy efficient option including electronic fluorescents, discharge lights or even LED's.

Match tractor and implement combinations for optimum output. Pay particular attention to the detailed points including maintenance, tyre pressure setting and ballasting.

Repair water leaks in irrigation pipes and carefully control pump settings and operation. Consider installing variable speed drives on pump sets.

Use simple automatic controls such as time switches, occupancy sensors and thermostats on energy consuming equipment in worker facilities.

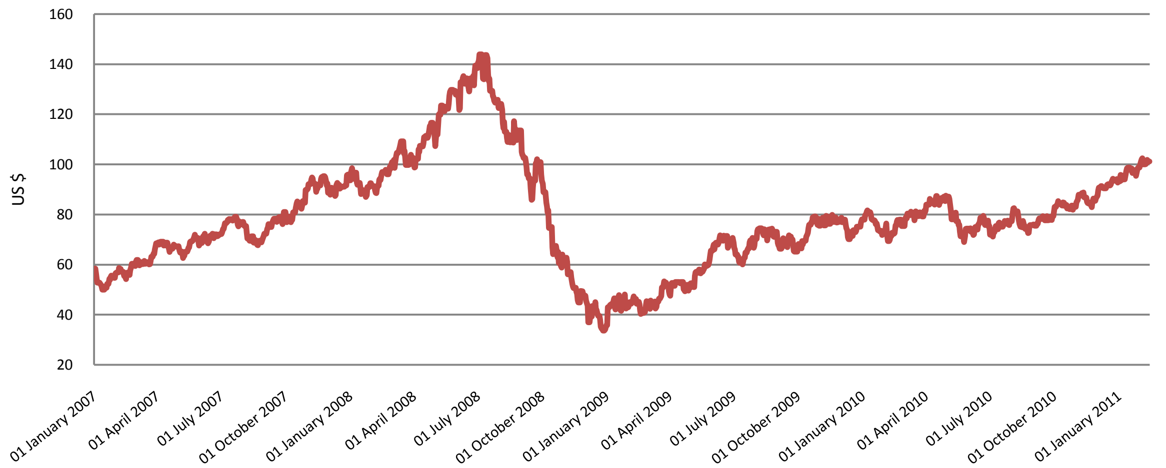
SCIENCE SECTION

Background & Introduction

Why is energy saving important?

Energy prices have continually increased for a number of years, and although prices stabilised through 2009 and the early part of 2010, the continued upward trend has now returned. This is illustrated in Figure 1 below which shows how the cost of crude oil since 2007.

Figure 1- Historic Oil Prices (US $ / Barrel Brent Crude)



The economic recession depressed prices in the late 2000's, but prices have steadily risen again as global markets have recovered and demands for energy have increased. This, added to increasing unrest in key energy producing areas such as the Middle East, means that energy market analysts are repeatedly predicting long term future price increases.

Concerns over climate change are also adding to price pressures. The UK Government has introduced a range of new policies to stimulate reduced CO_2 emissions through improved energy efficiency and increased uptake of renewable energy. These come either in the form of 'Carbon Taxes' or incentives for businesses which operate at best practice levels. Companies which embrace these Government policies will be able to access new business opportunities, whereas those who choose to ignore them will face additional energy cost increases which will inevitably impact on the viability of their business.

Finally customers and consumers are now looking for ‘low carbon’ produce. This trend was initiated by the leading high street retailers adopting the concept of ‘carbon footprints’ and carbon labelling for their products. Since then there has been considerable debate on the value of carbon footprints and how they should be measured, and whilst this has left a degree of confusion, a clear message is that growers must seek out ways to reduce their carbon emissions in the future.

Taking all of these factors into consideration, growers now need to seek out practical and cost effective ways to reduce energy consumption, costs and environmental impact. It is also important that producers have access to impartial guidance on what techniques are best for their own business.

The results of this project provide a starting point for field vegetable producers who want to implement energy efficiency improvements. The information and recommendations provided here are derived from data which quantifies the energy currently used by a number of key field vegetable producers and identifies where cost effective improvements can be made.

In carrying out this work the objectives of the project were to:

Identify and comment on the current standards of energy efficiency of a number of key field vegetable enterprises

Establish how energy costs and CO_2 emissions could be reduced through the implementation of energy saving measures and, if appropriate, renewable energy systems

Highlight any knowledge and/or skills gaps and make recommendations for future work

Provide simple information to help growers of field vegetables in the UK improve their energy & environmental performance

Energy use assessments

Six enterprises representing a broad cross section of the UK field vegetable sector were selected through consultation with industry representatives. Each farm was then visited by a Farm Energy consultant to carry out an energy use assessment which identified key energy information including:

- Current energy use quantities and running costs for existing systems

- Equipment configuration, capacities and operation / management methods
- Critical operating criteria

Whilst carrying out the assessments the energy efficiency of the existing processes / equipment was assessed and a simple energy saving action plan prepared. This action plan highlights the savings which could be readily achieved by each of the businesses and the cost effectiveness of the measures that were recommended.

The six farms assessed were;

Site A:	A vining pea enterprise that also produces cereals.
Site B:	A producer of salad onions and other assorted vegetable crops (including asparagus, French beans, stick beans etc.). Winter wheat is also grown.
Site C:	A carrot processing and packing facility.
Site D:	A producer of Brussels sprouts and assorted leafy vegetables.
Site E:	A producer of dry bulb onions. Potatoes and cereals are also grown.
Site F:	An enterprise producing assorted Brassica crops.

For reference, the combined production / outputs of the six sites contributing to the energy assessments were:

- 65,000 tonnes carrots (only processing output was assessed)
- 446 hectares salad onions
- 260 Hectares of vining peas (growing only)
- 115 hectares of beans
- 211 hectares Asparagus
- 2,090 hectares Brassicas

The quantity of onions produced by participant E was not specified.

The results of assessments are given in section 4 of this report and individual energy action plans for each of the enterprises are given in Appendix One.

Energy saving technology assessments

The findings from the work described in section 3.1 above were used to identify key energy use areas and energy equipment technologies that were in common use across the range of enterprises examined. The findings were used in conjunction with the knowledge and experience of the project delivery team to determine which approaches offered best potential for field vegetable growers wanting to reduce their energy consumption.

Each technology was assessed according to:

- How any potential upgrade might integrate with the existing systems and methods of work
- Any potential impacts on output and/or produce quality
- The potential for wider use across all of the enterprise
- How much energy (and CO_2) could be saved and the cost reductions that would result.

The technologies that were identified as having significant future potential for commercial uptake were determined, and where any further work is needed to fill current knowledge gaps this is highlighted.

The results of this work component are described and discussed in section 5 of this report.

'Top-Ten Energy Efficiency Tips'

Using the findings from each of the farms surveyed a list of the 'top-ten tips' for energy saving on field vegetable enterprises has been devised. It is recommended that growers should use this list as the starting position for an energy saving action plan for their own business.

The top-ten list is given in Appendix Two.

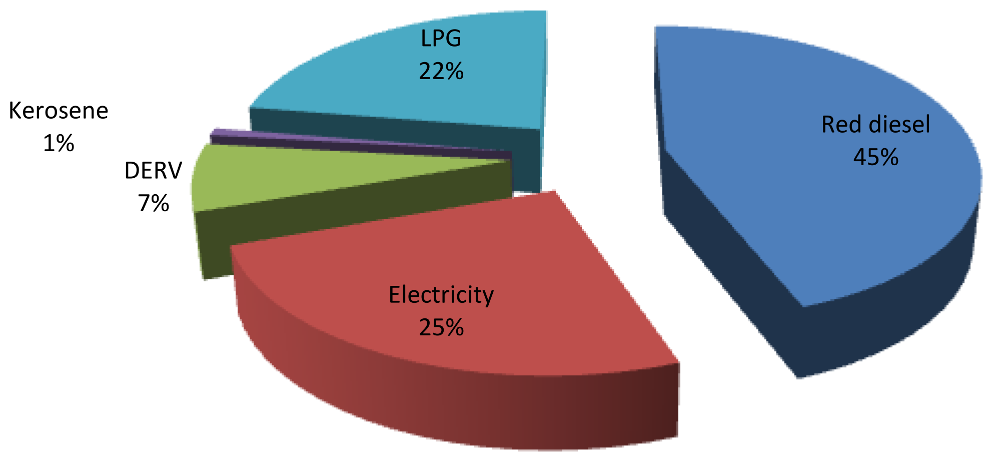
Survey Results

Fuel types used and fuel splits

The six enterprises consumed a total 26,969 MWH of energy split between, electricity, red diesel, DERV, LPG and kerosene.

The fuel type split is shown in Figure 2 below.

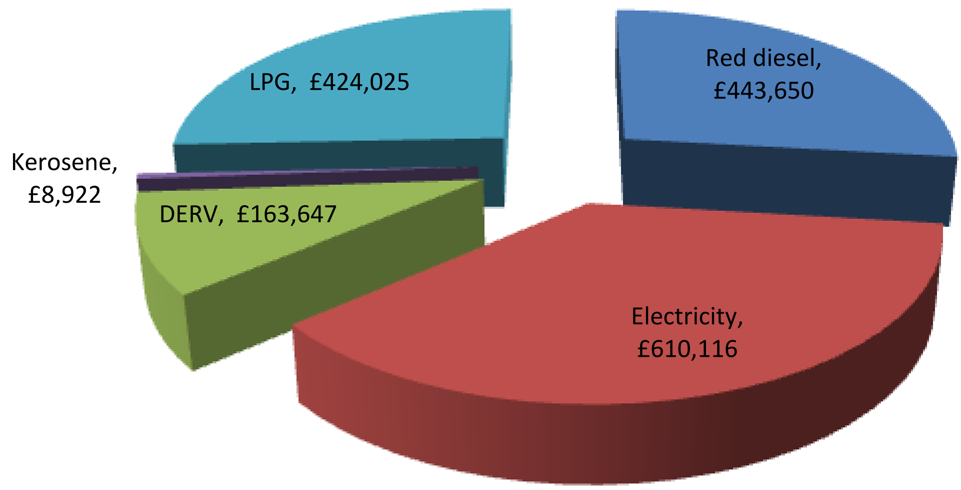
Figure 2 - Energy split between fuel type for the sites assessed



Total energy cost for the six sites is £1,650,360.

The costs of energy used in the calculations in this section and throughout the report are shown in the table below. Figure 3 shows the fuel cost split.

Figure 3 - Energy cost split between fuel type for the sites assessed



Fuel type	Purchased units	Cost per purchased unit	Cost per kWh
Electricity	kWh	£0.08	£0.08
Red diesel	Litres	£0.40	£0.037
LPG	Litres	£0.52	£0.07
DERV	Litres	£0.90	£0.082
Kerosene	Litres	£0.45	£0.043

The chart shows that electricity represents the largest energy cost component for field vegetable producers. In terms of net energy use it represents the second largest energy use behind red diesel. Energy consumption reductions in electricity, LPG and diesel should therefore be the highest priority for the energy conscious grower.

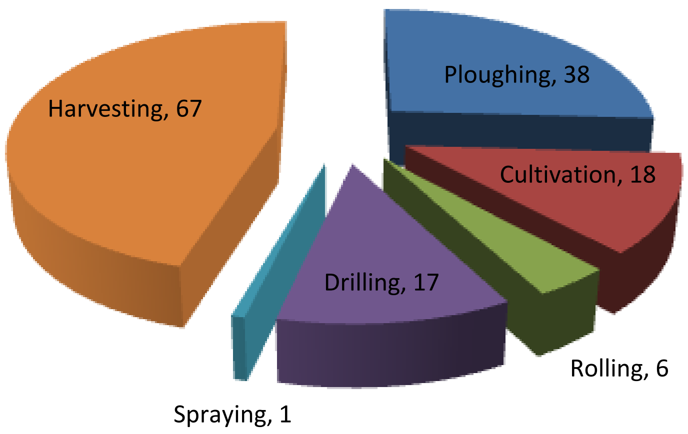
Technical areas

Field operations

Red diesel is the highest energy component input to field operations. Surprisingly there is very little information available regarding consumption patterns and use of this fuel. On farm, most diesel consumption data is derived from deliveries of fuel to tank via invoices from the suppliers. With this limited information it is very difficult to ascertain exactly where energy is being used and therefore where to concentrate effort to save it.

Site A did however have some good information about several of the field operations. From this data, and by using calculations based on tractor size and specific fuel consumptions, it was possible to derive the following energy consumption splits.

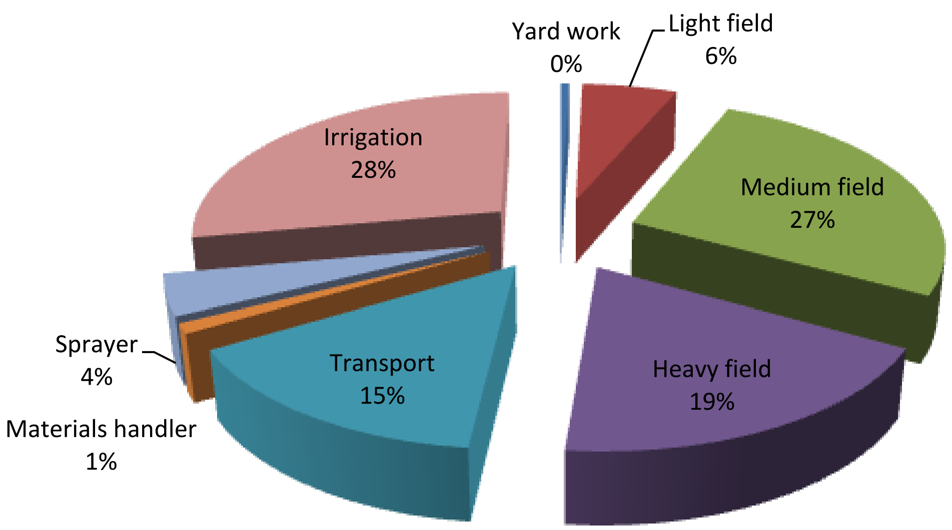
Figure 4 - Diesel use (litres/ha) for various field operations (vining pea production)



The data is based on a single site producing peas. The split is unlikely to be the same as a site producing a different type of vegetable or a combination of crops.

The following chart comprises data from Site B. The data available did not allow allocation to individual field operations as with the previous example, but still give a useful breakdown.

Figure 5 - Breakdown of diesel consumption for site B



In this example, energy for transport represents a much larger component of the red diesel consumption. This is because this company has several sites spread geographically in a radius of 30 miles. Energy use for spraying is also shown. The sprayers also use significantly more energy than Site A which is an effect of increased transport requirements.

Cultivations

The largest proportion of diesel use is for cultivations – in the example of Site A above, 54% of the energy is used for field cultivations. The energy consumption is affected by several factors:

- Type and condition of the soil
- Required cultivations for the vegetable type
- Ploughing depth
- Overlap
- Headland losses
- Correct equipment set up including ballasting, tyre pressures etc
- Driver behaviour
- Tractor suitability

Excess energy use as a result of any of these factors being less than optimum can be corrected by spending time and effort establishing the most suitable operational parameters for each task (for example, tractor ballasting, plough setting, etc.). This is inevitably compromised by operational constraints – pressure to complete work in a limited time and / or unpredictable factors like the weather.

Tractor selection has a significant effect on the energy used in cultivations. In the past, tractor efficiency has not been high on the list of requirement of most farmers. Factors such as power, manufacturer, suitability, dealership support and cost have been considered to be more important. The dearth of information available about fuel consumption is testament to this.

This situation is changing and there has been much work carried out by organisations like Nebraska Test Laboratory, OECD and the German Agricultural College (DLG) to determine tractor specific fuel consumptions. The DLG *Powermix* test aims to replicate real work applications and provide fuel consumption information in different applications and at different load rates.

The following table is a compilation of some of the results for 4 different tractors.

Manufacturer	Model	Rated power	Ploughing 100% load	Ploughing 60% load	Rotary harrow 100% load	Rotary harrow 70% load	Rotary harrow 40% load
					Diesel use		
		kW	g/kWh	g/kWh	g/kWh	g/kWh	g/kWh
New Holland	T7260	158	248	260	237	238	272
New Holland	T7270	168	266	263	234	239	272
Case	Puma 230	168	266	263	234	239	272
John Deere	8345R	254	259	248	236	247	278

The type of information given by the DLG *Powermix* is useful in comparing tractors because, just like MPG figures for cars, it gives an indication of efficiency. When choosing a tractor using this information the purchaser must consider the most likely use for the machine so that the correct efficiency is used, multi-purpose tractors are the most difficult.

At the moment the *Powermix* test results only show a few tractors models and multiple branding of the same machine lead to some duplication of information (see Puma 230 and New Holland T7.270 in the table above).

Tier 3 engines are the standard engine category for all tractors built after 2006 in energy efficiency terms the move to Tier 3 was a backward step because of the type of exhaust gas cleaning required get NOx and particulates emissions to stated levels. Tier 4 engines are due to be introduced for moving machinery in 2012. Tier 4 engines employ an improved type of emissions cleaning (catalytic converters) which gives improved fuel efficiency. This is of the order of 5%.

Chemical and fertiliser applications

Applying chemicals and fertilisers contributes a relatively small proportion to total field operation energy consumption. This is a relatively infrequent and low power operation, the significant proportion of which is often the travel from farmyard to field. Additionally the coverage of a typical farm sprayer (20m +) means the number of passes in a field are less than for other types of field work.

The efficiency of self propelled sprayers is thought to be particularly poor. This is because the machines have large engines with relatively inefficient hydrostatic transmissions. Hydrostatic transmissions are inefficient because they are required to respond quickly and therefore the engine is not often operating at its most efficient point. The benefits of such transmissions are their ability to be infinitely variable in regards to torque and power output and their flexibility with regards to wheel configuration, especially height.

Considering the efficiency of spraying operations therefore becomes an issue of application rates and overlap rather than equipment. Reducing overlap through tramline systems and GPS will help prevent over application and ensure the most energy efficient spraying.

Harvesting

Harvesting takes an estimated 45% of the field operations diesel use for Site A. This is entirely within expected limits especially because in the example data used this is a combined operation and uses a co-operative owned machine that does a reasonable amount of travel between farms. Harvesting, as with other field operations relies on internal combustion engine efficiency and minimising field passes to use the least amount of fuel.

Harvesting machinery is expensive and historically repairing existing machinery was more cost effective than replacement. Machines less than five years old now make up a significant proportion of the machinery stock as a result of the drive to bigger field size and more contract harvesting. Overall efficiency in this area is therefore expected to have risen quickly in recent years

Transport

Energy for transport, haulage and movement of machinery is a hugely variable component of a site's energy demand. For example Site B used 15% of their red diesel for transport and approximately 1.5 times as much DERV. On Site C no red diesel was used for transport and 12% of their total energy consumption was DERV.

Produce transport by tractor and trailer is a common practice in this sector. The cost of red diesel versus DERV makes this an attractive option. There are obviously legal limitations as to the type of haulage that can be done with a tractor. Choosing a tractor mostly for road haulage duties combined with occasional field work makes JCB's Fastrac the machine of choice. Typically the fuel consumption for these tractors in the range 5 to 7 miles per gallon.

Transport of people by coach or minibus is an efficient way of getting lots of workers to a site; there is little alternative in terms of type of transport. Efficiencies can be made in this area through reducing the miles transported and by using more efficient vehicles. Getting workers to make their own way to site can bring its own problems such as the logistics of parking numerous vehicles on rural roads. That does not reduce overall emissions, but just makes emissions the workers responsibility.

Storage

Long term produce storage was only carried out on Site E (Onions). The site has a refrigerated storage capacity of 13,900 tonnes and an ambient storage capacity of 5,400 tonnes. Data from one store was made available (refrigerated 2,000 tonne box store) and this shows an energy consumption of 130 kWh/tonne. Ambient storage will have less energy consumption not least because of the shorter storage season. Estimated energy consumption in the ambient stores based on the available data is 90 kWh/tonne.

Total energy consumption for onion storage is shown in the table below.

Type of storage	kWh/tonne	Total tonnage	kWh if all stores full
Refrigerated	130	13,900	1,807,000
Ambient	90	5,400	486,000
Total		19,300	2,293,000

The main stores are refrigerated box stores that have been recently built. They are generally in excellent structural condition and have been well designed and thought out. There are some issues with air distribution within the stores leading to warm spots in places. This is because of a reduced airflow at those points. Consequently at times the rest of the store is overcooled to compensate. Balancing the airflow through the duct apertures will help to resolve this problem and reduce energy consumption.

Vegetable stores are not always like the ones seen on Site E. Work carried out for the Potato Council and privately for a large vegetable producer recently show there is a huge difference between best and worst performing stores. The best performing stores can often be using half the energy of the worst performers.

Typical problems in vegetable storage are:

- Unbalanced airflows
- Poor store structure and insulation
- Badly fitting doors
- Faulty louvres
- Mismatched or unsuitable fans
- Leaky ducts
- Poor refrigeration efficiency
- Blocked or iced evaporators
- Poorly sited and blocked condensers
- Reduced refrigerant levels and lack of maintenance
- Compromised control
- Poorly or non calibrated temperature probes
- Poorly sited probes
- Single sensor control

In addition many stores do not have the ability to make use of ambient cooling when it is available. Ambient cooling is hugely variable from year to year. Making use of this cooling when it is available relies on a good store controller.

Packing and short term refrigeration

All but one of the sites surveyed carried out produce packing, crop cooling and short term storage. None of the sites had separately sub-metered electrical supplies dedicated to the packing facilities and the following table shows estimates of the energy proportions for packing and short term storage at the sites where information could be sensibly inferred.

Site	kWh used	% of company electricity	% of company total energy	% of all six sites total energy
Site B	1,394,342	62%	17%	5%
Site C	914,325	88%	57%	3.4%
Site D	51,084	82%	5.5%	0.2%
Site F	845,000	85%	11.2%	3.1%

Common areas of energy use in order of consumption are:

- Refrigeration - estimated 70%
- Compressed air - estimated 15%
- Motors and drives and pumps - estimated 15%

Refrigeration is used to remove field heat and cool the produce to the required packing and customer specification temperatures. Refrigerated stores and packing facilities on most of the sites were observed to have grown along with the business leading to a variety of types, systems and converted buildings. With such a diversity of cooling facilities and refrigeration plant, energy efficiency suffers. Recognising this, at least one of the companies surveyed was planning on moving to a dedicated facility and another was planning upgrading the existing site.

Problems observed in refrigerated areas were similar to those seen in long term storage:

- Leaky doors - not all sites had fast acting doors. For those that did have fast acting doors some damage was evident where careless forklift drivers or accidents had damaged the frames.
- Blocked and iced evaporators
- Deterioration of cold store fabric leading to condensation on produce and the floor
- Lack of regular refrigeration maintenance
- Improper siting of condenser units

Other uses of refrigeration include hydro coolers, vacuum chillers and blast chillers for rapid removal of field heat. These were generally observed to be in good condition. Blast and vacuum chilling is becoming less popular and one site was actively seeking to move away from its use.

Compressed air is in common use for operation of packing machines. This is delivered through a network of pipes from a remote unit. Leaks from these systems are common and this can reduce the efficiency of compressed air even further than its inherent inefficiency. Audible leaks are commonplace and indicate a considerable waste of energy. Ultrasonic leak detection is a useful technique which can be adopted to identify leak problems.

A significant amount of energy is also used for motors, drives in materials handling and water pumping. Good design of systems reducing pumping distance and pressure loss can help reduce energy consumption. Most of the motors used for pumping and for conveyers etc are standard efficiency motors which are 3 to 5% less efficient than high efficiency motors. The potential for improvements in efficiency is therefore significant.

Lighting

The most prevalent lighting type used in the sites surveyed was linear fluorescent in IP65 (water and dust resistant) fittings. Lighting did not account for as much energy use as refrigeration or motive power but it is an area where simple, cost effective improvements can be made.

Highly reflective internal building materials make the most of available light and generally most buildings showed good use of this feature (e.g. white plastisol coated walls). Also natural light was available in many areas.

In some cases though, lighting was over-specified and was not configured in such that it could be switched off in stages, or dimmed, to suit background conditions. The use of automatic controls such as daylight sensors, time switches, etc. was not common.

The most common fluorescent light fitting in use was the ‘T8’ switch-start design. In efficiency terms these have been superseded by T5 electronic fittings. They show improvements in efficiency of 20% over the switch-start design. Whilst the high cost of changing fittings renders upgrading uneconomic, where new lighting is required these should be the standard.

Irrigation

Energy consumption of irrigation equipment is significant but very little, even basic information is available on energy performance or energy efficiency best practice techniques. In all cases the irrigation pumps were engine-driven by large diesel engines. Metering of these sets was limited to hours-run clocks and these were rarely read. Most of the sets are commercial purpose-built machines. Some vegetable producers have built their own machinery.

On site B irrigation is likely to use 25% of the purchased red diesel.

Potential for efficiency improvement is likely to be large. However, without sufficient metering information showing variations in performance between the best and the worst, it is impossible to gauge.

Domestic facilities and worker accommodation

This is an area of energy use that is not applicable to all sites. Site B has the facility which housed most workers and had the best available energy data. Energy consumption for worker accommodation is electricity for lighting, refrigeration and domestic equipment and LPG for cooking and heating. Worker accommodation represented

- 30% of site electricity consumption
- 48% of site LPG consumption

With the energy cost including it in the overall charge for accommodation, there was no incentive for workers to limit their energy use. Essentially the only control the farm business has on energy use in this area is to ensure that equipment supplied is intrinsically energy efficient. Therefore low energy lighting and cooking and improved insulation must be key issues.

In communal areas automatic controls of appliances and lights and door closers are the sort of important tools that will lead to lower energy use.

Discussion

General energy management practices

From the evidence of the energy use assessments carried out, the majority of participants did not have ready access to accurate energy consumption data. Whilst all of the contributors to this study knew how much they were spending on energy (and how this related to the budgets they have set), they did not have accurate information about the amounts of energy (e.g. kWh, litres of diesel etc.) they were using, or how their consumption related to output.

In most cases the energy data came from supplier invoices, with the grower trusting that the supplier the information was correct. Unfortunately energy supplier invoices are invariably inaccurate, and this is particularly the case with utilities such as electricity. To account for this, growers should take their own energy meter readings or collect data from storage tank levels etc. to compile more accurate and reliable data from which consumption can be calculated.

A general rule that applies to all aspects of energy management is, *"If you can't measure how much energy you are using, you don't know how efficient you are, and you can't make improvements"*. Advice from the Carbon Trust is that implementing accurate energy monitoring and setting realistic energy reduction targets will save around 10%; and that is without any additional investment in energy reduction technologies. Therefore the process of collecting and analysing accurate energy use information can give substantial financial savings for little or no capital investment.

Further savings can be achieved through a more detailed understanding of the energy use patterns of the individual end uses on a business. For example how much energy is used for storage, for irrigation, by tractors, by the packhouse etc? Savings come from an ability to identify times when unexpected use occurs, but in the majority of cases this requires the installation of additional energy sub-meters.

In the majority of cases the energy consumption of specific facilities such as a crop store, cold room, or packing line is not measured with its own dedicated energy meters. This is because the common arrangement is that supplies (and meters) are shared across a number of facilities on the farm. This means that the amount of energy used for each individual end use is difficult to determine without making some general assumptions.

Accurately measuring the amount of energy used for a specific use allows energy consumption to be related to an output metric. For example accurate energy data for a crop store allows use to be related to the quantity of crop stored, storage duration, and weather conditions etc. Once data of this detail is available storage performance indices can be calculated and improvement targets set and assessed.

The value of this sort of data has been demonstrated through the results of the Potato Council project ref. R401. This project compared the energy performance of a selection of on farm potato stores by collecting energy sub-meter data and relating the information to the amount of crop stored. The project produced some startling results and showed that stores which were claimed to be efficient often performed worse than seemingly inferior facilities.

This principle applies to all energy uses, whether it be tractor diesel use, irrigation pump electricity consumption or store electricity consumption. Obtaining appropriate and accurate energy consumption data is therefore recommended as the starting point for all field vegetable farm energy improvement plans.

Good energy management at an overall company level also extends to simple things such as drawing up a company energy policy and securing employee commitment by communicating the energy saving aims and achievements of the organisation. The majority of the organisations assessed in this project did not do this, and whilst many growers may see it as another item of administration burden, companies who take this approach have shown that it can make a significant contribution to energy saving by developing a culture of cutting out unwanted use. Also, many of the leading customers for produce including the supermarkets will expect their suppliers to be implementing this type of energy management practice.

Field operations

Reducing the energy consumption of tractors and self-propelled machinery is one of the most difficult areas for growers to tackle. This is largely because of a shortage of data on tractor fuel use and a lack of understanding of the factors that affect the consumption of tractor & implement combinations. Added to this there are a number of cultural issues associated with tractor selection and operation including;

A ‘get the job done’ attitude tends to prevail with both farm managers and machine operators. Timeliness and work-rate are the key issues when selecting a machine to do a job, and in the majority of cases, a ‘comfort factor’ is often built in when a tractor and implement combination are being chosen.

The make and model of tractor used by a farm business tend to be driven by the purchase price of a machine and the relationship with the local dealer for providing ongoing customer support (including maintenance and servicing). This tends to restrict the choice of machines for many and could prohibit purchasing the most efficient makes and/or models.

Fuel efficiency data is not readily available for the full range of tractors and machines that are available. Unlike cars, where fuel consumption and emissions data is now a pre-requisite, data for tractors is rather scant and comes from a range of sources. The following reply to a request for fuel consumption information from a leading tractor manufacturer highlights the difficulty in getting reliable data:

“Thank you for your enquiry. I am afraid we do not distribute fuel consumption information because the results are so variable and there is no industry standard benchmark test. The fuel usage varies depending on so many factors including the application, terrain, driver, speed etc. The most accurate way to get this information would be to measure the client's vehicles doing their job.”

Some more complete fuel use data is now available from DLG, a German testing and performance organisation. However the data provided is not straightforward to understand and tests are only carried out at the request of the manufacturer. This makes the information of limited value at the moment.

Energy reduction options

Field Equipment

Despite the apparent difficulties with reducing tractor fuel consumption there are a range of readily available options which are summarised in the following table:

Energy Saving Technology / Technique	Description	Saving Potential
Driver education and training	There is a growing body of evidence from other industries (particularly road haulage) that driver education and training can produce significant reductions in fuel consumption. To be effective, accurate fuel use records are needed so that individual drivers can see how they perform compared to others see section 5.1 above). The evidence from this project is that growers do not have sufficient data to 'benchmark' machine operation or driver performance; or if they do have the data it is not readily available or shared with equipment operators.	10% +
Tractor selection	Fuel efficiency should be one of the key factors which a grower takes into consideration when purchasing a new machine. Significant differences can exist between machines that seemingly have the same performance. By accessing fuel consumption data (particularly from independent sources such as DLG) more informed decisions can be made	5%
Tier 4 / Tier 3 Engines	More stringent emissions regulations are leading to the introduction of upgraded engine designs. Known as Tier 4, these engines use technologies such as catalytic converters to bring exhaust emissions in line with the latest regulations. One of the benefits of this new technology is that the new designs are more energy efficient that the existing ones (particularly the current Tier 3 standard).	5 to 10%
Tractor / implement matching	A wealth of R&D was carried out in the 1980's and early 1990's to determine how tractor set-up and implement matching can improve work rates and fuel efficiency. Organisations such as Silsoe Research Institute (formerly the National Institute of Agricultural Engineering) produced many recommendations on driving technique, tyre selection, ballasting, implement matching etc. The evidence is that much of this work is not applied in practice, largely because of cultural issues and the difficulty and time spent in changing tractor set-up when a machine is used to perform numerous tasks.	15%
'Precision Farming'	Adopting these techniques (which use GPS mapping) prevents unnecessary operations and allows fieldwork to be more accurately carried out. They are particularly useful for spray and fertiliser applications as they allow the treatments to be concentrated on where they are most beneficial. Overlapping and double applications / operations are also minimised. The precise savings have not been independently verified, but leading cereal farmers who have adopted the technology are claiming significant savings.	10%

Considering the approaches listed above, it is not unreasonable to expect that growers could reduce their current diesel use for tractors by 15%. The initial approaches by which this can be achieved are listed in the 'Top-Ten tips' given in Appendix One of this report. In addition to the above list of fully developed technologies, some other less developed techniques have the potential to reduce fuel use. These include 'minimum tillage' techniques and controlled traffic systems. As yet both of these approaches are not commercially developed and whether they can be widely used in vegetable production is not fully known.

Storage

Crop storage is carried out in a variety of facilities depending on the crop that is being produced. For example onions are long-term stored in a mixture of ambient air stores and refrigerated stores, whereas carrots are stored for short periods in refrigerated holding stores after the 'field heat' has been removed with a hydro-cooler (where necessary) and the crop has been graded and / or packed.

Despite this variation in requirements, many of the basic technologies are common to all of the facilities in common use. These technologies and the options for upgrade are listed in the table below.

Energy Saving Technology	Description	Saving Potential
Energy Monitoring and targeting	See section 5.1 above. If necessary sub-meters should be installed to allow accurate energy consumption information to be gathered and used alongside store data to produce energy use metrics and improvement targets (e.g. kWh/tonne/month stored)	5% +
Insulation	Effective insulation is required to reduce heat gains and reduce the demand on cooling equipment. Mechanical damage to insulation is a common occurrence as it is caused by accidental impacts with handling machines, storage boxes etc. When damage it occurs it should be promptly repaired to limit energy waste. Insulation materials can degrade over time, especially if they become wet. Also some older stores may have inadequate levels of insulation as the storage requirements may have changed (e.g. lower storage temperature, increased store loading etc.) since the store was originally designed and constructed. The current normal recommendation is that a U-value of between 0.3 and 0.4 $W/m^2/^oC$ is needed for most cold stores. Current ratings can be checked by calculation using the insulation specification and thickness and effectiveness can be determined using thermal imaging. Any store that does not meet this specification should be re-insulated or have an additional layer added to the existing material.	5%
Air leakage reduction	Common causes of air leakage are poor joins between insulation panels, damaged door seals, ineffective air inlet / outlet seals, open doors, refrigerant service entry points etc. Excessive air leakage allows warm ambient air to infiltrate into the store thereby increasing the demand for cooling. Improving air leakage is relatively straightforward and cheap to implement. Example upgrades are replacing door seals, fitting automatic door closers, sealing around pipe / cable entry points etc.	5 to 10%

Energy Saving Technology	Description	Saving Potential
Fan selection & airflow optimisation	Effective cooling and storage requires good even airflow throughout a store. To achieve this and ensure that energy is not wasted, fans should be carefully selected to meet their duty, and once in service they should be regularly maintained by cleaning the impeller blades, air intake grilles etc. More efficient fan designs are available and an example of this are fans which use an Electronically Commutated (EC) motor. This type of fan is well suited to low power applications (e.g. propeller fans, small centrifugal fans) of less than 5kW and it is used widely in modern commercial air conditioning applications. Energy savings of 15% are achieved when using fans with EC motors. Duct design and maintenance is also vitally important as poorly configured or blocked ducts impose excessive back pressures on fans which restrict airflow and increase energy consumption. Fan to duct transitions should be smooth, and all potential restriction points removed. This extends to the cleaning of ventilated floors (e.g. in onion stores) where blockage can occur due to soil build up etc.	15%
Maximising ambient cooling	When ambient air temperatures are sufficiently low 'free cooling' can be achieved by simply ventilating this air through the crop. This reduces the demands on refrigeration equipment and cuts energy consumption. Many long term stores (e.g. for dry bulb onions) have the facility to ventilate with either ambient or refrigerated air (or a mixture of the two), and this principle can be extended to other crops. Modifications are required to air intake systems and automatic controls are needed to optimise the system and ensure produce quality is not affected. Savings are dependent on crop requirements, storage period, weather conditions etc, but 20% is common in many installations.	20%

Energy Saving Technology	Description	Saving Potential
Refrigeration equipment upgrades	Current refrigeration designs that are in common use by field vegetable enterprises use fixed capacity control. Whilst some control is available through staged operation of compressors etc, the current designs are not efficient when operating at less than their maximum rated output. In most cases the refrigeration designs are some 15 to 20 years out of date when compared to those used in other areas of industry and commerce. New designs use technologies such as variable speed drive compressors, electronic expansion valves and floating head pressure controls to allow output to be closely match to the instantaneous cooling load. Using these advanced technologies can give energy savings of 40% of the refrigeration electrical demand. Another approach that has been demonstrated to give significant savings is ground source refrigeration. With this technology the conventional air cooled condenser is replaced with a condenser supplied with groundwater. This keeps the condensing coil under more controlled conditions and allows the refrigeration cycle to operate more efficiently. HDC project CP57 investigated using this technology on a refrigerated packhouse operating at approximately 12^{o}C and savings of 42% were achieved compared to a conventional system. The savings will be reduced when lower temperature storage is required, but ground source refrigeration still offers significant energy saving potential. In addition to energy savings there are other potential advantages to using to newer refrigeration systems designs. By applying the technologies described above the refrigeration system works closer to its design capability for a greater proportion of its operating time; with the result being that the store environment is consistently held at the desired condition. This will have knock on effects on including improved crop quality, reduced dehydration etc.	40%
Control	Effective control of both the store environment and cooling equipment operation is essential if energy consumption is going to be minimised. A control system should be used which allows the desired store environment to be achieved whilst automating the operation of all the major energy consuming equipment. When in use the calibration and placement of sensors is vital. For example if the store temperature control measurement is inaccurate, energy consumption will not be optimised	15%

Packhouse equipment

The discussion relating to storage (and refrigeration) above is also applicable to packhouses. In addition to this, lighting is also a key area for improvement.

Many packing facilities use fluorescent lighting which operates for long hours all year round. If these lights are inefficient, significant energy waste will result. The most efficient design of fluorescent lighting uses electronic control gear and a slim "T5" tube which is 5/8 inch (16mm) in diameter. This compared to older designs including the most inefficient T12 (1 ½ inch / 38 mm diameter) tube which runs on an electromagnetic ballast. By switching to the most modern designs lighting energy savings of 40% can be achieved.

Irrigation

There is significant potential for savings in irrigation and there was little evidence was found during the assessments carried that producers have addressed (or were addressing) energy efficiency in this application area. The range of systems in commercial use is hugely variable and it ranges from old diesel engine driven pump-sets through to modern electric pump arrangements with variable speed (inverter) controls.

Energy and water data recording

Again the common message of lack of energy data and the need for improved monitoring (see section 5.1) applies in this area. None of the participants were able to provide data which related energy use to irrigation application quantities and water use. This meant that energy use metrics such as kWh / hectare·mm or kWh/m^3 were not known. Also the data did not seem to be readily available to allow the calculations to be made. Without this data benchmarking irrigation performance is not possible.

Producing accurate energy records for irrigation applications is likely to be relatively straightforward. Most irrigation installations have some water metering which allows the volume applied to be recorded. From the energy recording perspective electric pumps are often supplied from dedicated electric supplies with their own meter. Alternatively engine pump sets are fuelled from a dedicated portable diesel bowser, which if regularly dipped and recorded, can give accurate fuel use data. It is recommended therefore that, as a starting point, growers should start to record both energy and water application data so that they can compute kWh / hectare·mm figures and make comparisons between different installations.

Pump-set type

Pump set type has a significant effect on energy consumption and electric driven pumps are more efficient than engine driven ones. For example the efficiency of an electric motor is typically about 88% whereas an engine usually operates in the range of 35 to 40%. This means that when combined to a pump with around 75% efficiency, the overall efficiency of the pump and motor assembly is around 65% for electric and 27% for diesel. Clearly electric pumps therefore have the potential to be more effective.

The choice between electric and diesel pumps is often driven by fuel cost, and in the past the relatively low cost of diesel (compared to electricity) has meant that, despite their apparent lower efficiency, engine driven pumps have been popular with many producers. However, as diesel prices continue to rise, this balance is now changing.

Pump control

The other area for energy saving in irrigation is to match pump output to water needs. Pump selection and irrigation system design is based on selecting equipment that can meet the maximum duty required. For an irrigation pump this means that it must be able to deliver the required water flow rate (m^3/hour) against the maximum pressure on the system. Maximum pressure typically occurs when water is being pumped to the furthest point on the irrigation system using the maximum number of irrigators.

In practice however, maximum output is only required for a relatively short period. This means that for the majority of the time, traditionally configured and controlled pumps do not operate at optimum efficiency. By using improved controls, which in the case of an electric pump involves using a variable speed drive (also called an inverter drive), energy savings of the order of 40% can be achieved. The variable speed drive uses sensors in the irrigation lines (typically pressure sensors) to ensure that the irrigators are operating at optimum output.

Summary of energy saving options for various vegetable crops

The following tables summarise some of the most effective energy saving options for dry bulb onions, carrots and Brassicas.

In all of the tables the upgrade costs are based on current commercial costs and estimates of throughput on a typical field vegetable enterprise. Upgrade costs are also based on the additional cost of moving to the new technology. The exception to this is Tier 4 engines for tractors where costs are based on the total cost of a replacement tractor.

Cost benefit comparison for a range of upgrade options for dry bulb onions

Mitigation technique	Use category	Potential saving (%)	Typical Implementation Cost (£/tonne)	Energy Cost Savings (£/year)	Payback (years)
Precision farming	Fieldwork	10%	£1.25	0.18	6.9
Tier 4 engines	Fieldwork	10%	£12.50	0.18	69.4
Variable speed drives	Irrigation	30%	£1.00	0.153	6.5
High efficiency motors	Irrigation	3%	£0.10	0.0153	6.5
Engine control	Irrigation	30%	£1.25	0.153	8.2
Insulation upgrades	storage	10%	£5.00	0.64	7.8
Reduced air leakage	Storage	10%	£3.50	0.64	5.5
Controls	Storage	15%	£5.00	0.96	5.2
Improved refrigeration	Storage	40%	£10.00	2.56	3.9
Improved airflow distribution	Storage	10%	£5.00	0.64	7.8
High efficiency heaters	Drying (Storage)	10%	£5.00	0.855	5.8
Biomass heaters	Drying (Storage)	80%	£10.00	6.84	1.5
Controls	Drying (Storage)	15%	£5.00	1.2825	3.9
Energy management	All	10%	£1.00	1.746	0.6
Maintenance	All	10%	£1.00	1.746	0.6

Cost benefit comparison for a range of upgrade options for carrots

Mitigation technique	Use category	Potential saving (%)	Typical Implementation Cost (£/tonne)	Energy Cost Savings (£/year)	Payback (years)
Precision farming	Fieldwork	10%	£1.77	£0.31	5.7
Tier 4 engines	Fieldwork	20%	£17.73	£0.62	28.4
Variable speed drives	Irrigation	30%	£1.00	£0.15	6.5
High efficiency motors	Irrigation	3%	£0.10	£0.02	6.5
Engine control	Irrigation	30%	£1.25	£0.15	8.2
Controls	Storage	15%	£1.00	£0.24	4.2
Improved refrigeration	Storage	40%	£3.00	£0.64	4.7
Energy management	All	5%	£1.06	£0.27	3.9
Maintenance	All	10%	£1.06	£0.54	2.0

Cost benefit comparison for a range of upgrade options for Brassicas

Mitigation technique	Use category	Potential saving (%)	Typical Implementation Cost (£/tonne)	Energy Cost Savings (£/year)	Payback (years)
Precision farming	Fieldwork	10%	£2.50	£0.31	8.0
Tier 4 engines	Fieldwork	20%	£30.75	£0.62	49.3
Variable speed drives	Irrigation	30%	£1.00	£0.15	6.5
Engine control	Irrigation	20%	£1.25	£0.10	12.3
Controls	Storage	15%	£1.75	£0.24	7.3
Improved refrigeration	Storage	40%	£7.00	£0.64	10.9
Energy management	All	5%	£0.75	£0.27	2.8
Maintenance	All	10%	£0.75	£0.54	1.4

Alternative energy

Overview

The term alternative energy covers non-fossil fuel options, or what has come to be known as 'renewable energy'. This includes biofuels, solar Photo-Voltaic(PV), solar thermal, small-scale wind and biomass. Also included are options like heat recovery where an energy waste stream can be redirected to a useful process.

It is important to note, when considering alternative energy options and the value of renewable energy, that energy and carbon saved through the employment of energy efficiency techniques carries just as much value as renewable energy in terms of financial value and environmental damage mitigation. In fact, most analysts would score energy efficiency techniques higher in terms of their value because of their lower resource implementation, lower cost and better reliability. Therefore, the accepted approach when considering implementation of energy/carbon reduction is to firstly consider and implement cost effective energy efficiency techniques and then consider how the remaining energy use might be offset using alternative energy sources.

When it comes to the production of electricity from renewable sources, it is generally unhelpful to regard generation as a technique to replace the fossil grid-based electricity being used on site. Since electricity cannot be stored in a practical and economic way, true offsetting can only be achieved if the load profile of the energy use on site can be matched to the energy production profile of the renewable source. Matching a renewable generation resource like wind or solar to the use of electrical energy in field horticultural applications, for example, is almost impossible. It is therefore more realistic to regard the renewable electrical energy resource, either as a completely separate technical and business activity, or as something which is complementary to other sources, making a contribution to the base-load of energy requirement.

In the case of a renewable energy which can be stored - either temporarily (for example, solar heat), of for a longer periods (biofuels) - then direct offsetting of energy use is a more realistic concept.

Generally, renewable energy sources are capital intensive. Obtaining best financial performance from the techniques involves sizing equipment in such a way as to **maximise** operational output and value whilst **minimising** capital cost. This usually involves selection of equipment to work below what is termed the 'base-load' of the total site rather than sizing to meet the full peak energy demand. Although this might not meet the idealistic aspirations of the business that wishes to eliminate all its fossil fuel based energy use, it will inevitably deliver the best economical solution whilst going a long way to meet sustainability targets.

The following sections discuss specific alternative energy options.

Biofuels

Biofuels include the utilisation of oil seeds and grain products to produce biodiesel or ethanol as a replacement to fossil fuel alternatives.

With an all-year demand for diesel by tractors and other mobile equipment there would seem to be a natural fit between the production of biodiesel from oilseed rape, and land-based agriculture.

Biodiesel can be used in conventional diesel engines up to an inclusion rate of 15% – commercial research is starting to reveal that higher inclusion rates may well be practical in the future. Simple on-farm cold-press technologies can produce an acceptable product for current recommended levels of use. The financial benefits are marginal, but are improving as the price of oil makes diesel more expensive.

There are a number of environmental arguments which include the consideration of the net greenhouse gas emissions from the production of biodiesel, and the issue of diverting land use away from food production. Some critics state that, from an overall environmental point of view, biodiesel offers no advantages over conventional fossil fuel diesel. As such, production of biofuel has not been embraced by politicians and policymakers as much as energy from wind, solar and biomass. Consequently the support systems which are needed to make this alternative energy source competitive are not as evident.

The practical production balance for biodiesel on a typical 30 ha vegetable production enterprise is illustrated below:

Field vegetable area	30 ha
Fuel use	4,800 Litres per annum
15% displacement bio-diesel	720 Litres per year
Tonnage of oil seed required to produce displacement	1.58 tonnes
Area required to grow the oil seed	0.5 ha
Approximate equipment cost for a crush pure plant oil pant	£7k
Production cost	58p / Litre
Gross saving compared with red diesel at 70p	33.1p / Litre (£238 per year)

Clearly, for this small use, a bespoke on-farm crushing system is not viable. Viability would improve with increased fuel use - either by including the use of a larger arable enterprise or possibly as a co-operative venture between a number of sites

Bioethanol production appears to be less useful mainly because the application of the end products tends to be limited to road vehicles and these have only limited direct involvement in field horticultural processes.

Solar PV

Land based agricultural businesses are well placed to take advantage of solar PV systems. Space for the panels is plentiful, either on the roofs of stores, general purpose agricultural buildings or in fields. Although the yield of solar PV is limited in density (peak $150W/m^2$) and the panels are expensive, the introduction of the feed-in tariff system has improved the economics of installation and long term operation quite markedly. The level of support for larger systems over 50 kW is currently under review by the government as it is felt that these systems may be inappropriately supported.

Solar PV cannot be regarded as a realistic base-load contributor for a farm as the output is diurnally variable, and almost totally limited to non-winter months. Nevertheless, as an income generator which can utilise available roof or land area and one that has some small potential for displacing overall energy consumption, it may have a valuable part to play in the renewable energy make-up of a field vegetable enterprise.

Wind

As with solar PV, small-scale wind power is easily adoptable by field agricultural businesses. For small-scale systems there tend to be less problems with planning and potential nuisance caused by noise of light flicker. Wind resource in open agricultural areas is better than for urban locations so yields are comparatively good.

Again the financial viability of small-scale wind systems has been revolutionised by the feed-in tariff system making wind one of the most attractive renewable energy sources in terms of overall return.

The unpredictability of wind means that it cannot be regarded as a full base-load contributor in most cases. Nevertheless for businesses that have a significant background energy use wind can make a contribution.

Larger scale wind farms may have a role in supporting enterprises with extensive refrigeration and pack houses. However they need to be regarded primarily as a stand-alone business investment as the financial case for their establishment is long-term and mostly based on guaranteed feed-in tariff rates

Biomass

Agricultural biomass in the form of wood, straw or vegetable matter can be utilised in energy production. Dry wood and straw can be burnt to produce hot air or water and vegetable matter can be digested to produce gas which then can be burnt or used in an engine to produce electricity.

For most field horticultural businesses, heat energy in the form of hot water or hot air is not widely used. The exceptions are heating for harvest labour accommodation, offices and heat for the drying of onions.

As is often the case with renewable energy systems, the recovery of capital costs is the major issue. Where the heating season is relatively short and heating peak demand is high, high capital costs systems are not economically favourable compared with the crude application of heat from fossil fuel sources.

The impending Renewable Heat Incentive (RHI) may change the economics of the application of renewable heat based on biomass. (ref financial incentives section)

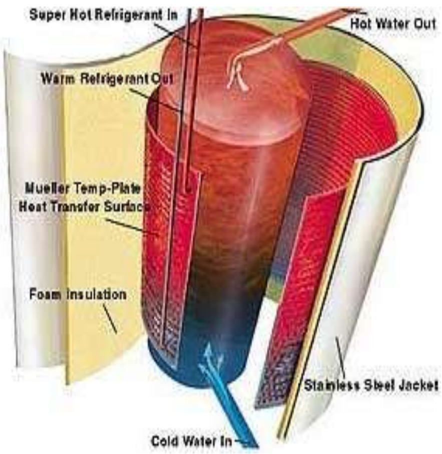
Anaerobic digestion

Anaerobic digestion which produces electricity from gas engines has a better fit to field vegetable energy requirements especially where there may be significant base electricity load for refrigeration. Some benefit may also be derived from the ability to deal with waste vegetable matter or neighbouring animal slurries, and from the value of fertiliser in the digestate. Capital costs are high and systems need to be quite large, to benefit from economies of scale.

Packaged systems from the continent tend to require over 15,000 tonnes of feedstock per year for viability. The overall economics depends on a balance of income from electricity generated, gate fees for digestible waste, excess hot water and the fertiliser value of digestate.

The development of small scale anaerobic digestion promises to provide a better fit for field horticulture.

Heat recovery



Energy can be recovered from the condenser coils of refrigeration equipment and used to heat water. Where the use of domestic hot water is significant, heat recovery can make a useful contribution to the energy used. Hot water demands from seasonal worker accommodation provide a good match to the availability of heat.

Clearly for this to be practical, the condenser coils of the refrigeration equipment and the place where the hot water is to be used needs to be relatively close.

Recommendations and Conclusions

The findings of this work suggest that growers of field vegetable crops have considerable scope for making energy savings. Measures ranging from simple energy management techniques thorough to more complex energy saving technologies and renewable energy generation can all contribute to reduced energy costs and improved energy sustainability.

The assessments carried out by this project showed that most of the businesses did not keep energy records that were of sufficient detail to allow energy benchmarking to be carried out. This also means that it was not possible to accurately identify the "energy waste hotspots". As a result it is recommended that all businesses should implement better energy recording systems and carry out analyses that relate energy consumption and cost to production. This alone will produce energy savings of around 10% for most businesses as it will give them a better insight into energy use patterns and allow them to cut out unnecessary consumption.

The recommendations for simple upgrades are summarised in a "top-ten tips" list that is given in Appendix Two of this report. It is suggested that all field vegetable producers should use these action points as a starting point for implementing energy saving actions which are relevant to their business.

In the longer term there are several areas where growers can benefit from investing in more complex energy saving technologies. These include advanced refrigeration technologies, efficient tractor selection and operation, and irrigation equipment selection and operation.

To successfully implement these more advanced technologies in practice, growers will need more information about the energy saving performance, how to use the technologies on a commercial farm and impartial evidence of the long term validity of the savings. To do this more work will be needed, particularly at an on-farm demonstration level. Because of the cross sector nature of these technologies it is recommended that the field vegetable sector should liaise with other crop sector panels and AHDB Levy Companies, particularly Potato Council Ltd (who have a common interest in crop cooling/storage, irrigation and field machinery) and HGCA.

Knowledge and Technology Transfer

Presentation to Field Vegetable Conference, East of England Showground, Peterborough, 1st February 2011.

Presentation to British Carrot Growers Association Technical Seminar, PGRO, Thornhaugh Peterborough, 7th April 2011

HDC News Article planned for spring 2011

Continue promotion of the results through HDC's energy technology transfer project, GrowSave.

Appendices

Appendix One - Energy action plans

Site A

The energy consumption at Site A is all red diesel through a combination of different machinery. Some of the machinery is under the control of the growers co-operative and therefore the farmer has little influence on the efficiencies of this machinery. The following actions are proposed.

	Detail	Cost/ benefit
Fit fuel metering and keep fuel log for tractors	Although the farm had the best fuel usage records of all the farms visited this could still be improved. Detailed information regarding consumptions and the conditions in which tasks were undertaken is key to being able to specify improvements. A simple log sheet recording fuel fill ups and the task carried out between fill ups is a good starting point. More advanced systems that automatically collect relevant data will give more useful information at increased cost.	Likely cost £500 (time and tank meter) Saving - 10% of red diesel 4,762kWh (441 litres) £189 pa
Ensure all tractors are set up correctly and most efficiently for each task	This could have the biggest immediate effect on energy consumption, by spending extra time ensuring tyre pressures, ballasting and equipment settings are correct for the conditions and task will ensure the most efficient operation.	Estimated cost £500 for time Saving 15% red diesel use - 7,143 kWh (662 litres) £283
Investigate auto-steer and GPS technology for the tractors.	This has already been considered by the farmer and costs obtained. The benefits of these systems are to improve the efficiency of operations in the field by reducing overlap and ensuring the minimum travel. Systems are commercially available that can be moved from one vehicle to the next which minimises cost.	Cost £10,000 Cautious estimate 5–15% saving but needs investigation
Investigate minimum tillage systems	Discussions with the farmer on site established that they thought minimum tillage systems were not suitable for growing peas. However there was an acknowledgement that other members of the co-operative did use minimum tillage systems. Further investigation is required to determine the suitability and the cost/energy savings that would result.	Further investigation required
Consider fuel efficiency at the next machinery purchase	Improvements in tractor fuel efficiency are still small - Tier 4 engines are likely to have the biggest impact over the last few years. Whilst replacing a tractor for efficiency gains alone will not be economically sound it is a consideration when the time comes for replacement.	Extra cost £2,000 per tractor 5% saving 2,381kWh (221 litres) £94 per annum

Site B

Site B is hugely complex and most of the recommendations for all 6 sites will be applicable to this site also. There are many recommendations that could be made and the most important and different are given here.

	Detail	Cost/ benefit
Establish proper monitoring techniques for all energy consumption and analysis	As a very large enterprise it is all the more important that energy data gathering and monitoring is carried out. The analysis of the energy data should be carried out regularly and informed decisions made with regards to efficiencies. No one person can have knowledge about all aspects of this business and specialist advice should be sought where required. Realistic energy reduction targets should be set and reviewed regularly.	Cost - £10,000 (time and equipment) Saving 10% through increased awareness - 817,727 kWh £52,440
Fit water flow, water pressure and diesel monitoring to a selection of different irrigation pumps.	Site B is an ideal business to carry out an in depth irrigation efficiency study. There are several different types of pumps and good potential to get long term comparisons of seasonal data. This study will help the company make better informed choices about the efficiency of water application and would have similar industry wide benefits if carried out on behalf of the HDC. A comparison between diesel irrigation efficiency and electrical efficiency would also be worthwhile.	Cost £5,000 monitoring equipment Savings hugely variable
Carry out refrigeration efficiency inspections	Similarly to Action 2 above Site B is ideally placed to study refrigeration efficiencies. COP (coefficient of performance) monitoring is widely carried out in industry and resulting small changes in operation, refrigeration quantity and general maintenance can have big effects on efficiency without compromising system or produce cooling. Additionally a regular maintenance inspection, concentrating on condenser and evaporator coil soiling will ensure the system operates efficiently and lasts longer. This is especially important during the summer when refrigeration systems struggle to cope with warmer temperatures and are often blocked by dust and dirt.	Cost £6,000 (4 consultant days) Saving 20% refrigeration electricity use 210,100 kWh £16,800
Install electricity metering to temporary accommodation	By installing metering to temporary accommodation and rebilling the staff for the electricity they use consumption will be reduced. This will also ensure that abuses of the rules concerning high powered electrical equipment can be identified. Giving the staff a display of instantaneous power draw and energy consumption over the last 24hrs/week/month will act much like smart metering has done in domestic properties to reduce consumption.	Cost £200 per meter Saving 20% accommodation electricity - 90,534 kWh £saving will depend on payment arrangements with staff

Fit automatic lighting controls in communal areas and in the packhouse	In buildings where there is no obvious individual responsibility for energy consumption, automatic controls should be installed. The following are suggestions that might be considered: Light level sensors for packhouse Occupancy sensors for mess rooms/canteens/changing facilities Dawn to dusk sensors for communal facilities lighting Time switch override to ensure no lights are left on automatically out of hours	Cost £300 per control 15 controls - £4,500 Savings 10% lighting consumption - 16,600 kWh £1330 per annum
Consider changing tractor road transport machinery	The Fastracs owned by the company are good dual purpose machines however they spend almost their entire time road hauling produce to the packhouse from the fields. A more road focused machine that has similar off road capabilities is a Mercedes Unimog. These have reduced fuel consumption of 10-20% for road haulage applications. Currently they are too expensive to justify the saving however future increases in fuel costs could change this.	Requires further investigation and or road trials

Site C

Site C is a packing only facility largely using electricity. The following actions reflect this.

	Detail	Cost/ benefit
Purchase and use temporary sub-metering for larger items of equipment	Temporary data logging sub-metering will be invaluable to the company to ascertain the energy consumption and running cost of individual processes/equipment. This can be used to target the equipment with the highest potential and establish the impact that efficiencies have.	Cost £6,500 Savings - 10% 103,509 kWh £8,280
Monitor air compressor cycling and repair compressed air leaks	The compressed air systems were heard to have leaks; this is an indication of their inefficiency. A simple way to determine the inefficiency of the system is to monitor its overnight cycling. Any operation overnight will be to 'feed' the leaks, and by knowing the volume of accumulator and pipework the quantity of leaks – and hence energy consumption for leakage – can be ascertained. Audible leaks should be repaired straight away. Once all audible leaks have been identified, an ultrasonic leak detection should be carried out to find the other leaks. Similar surveys on industrial sites have reduced compressor energy consumption by 30%.	Cost £3,000 Saving 30% compressor energy 24,090 kWh £1,930 p.a.
Carry out refrigeration efficiency inspections	COP monitoring is widely carried out in industry and resulting small changes in operation, refrigeration quantity and general maintenance can have big effects on efficiency without compromising system or produce cooling. Additionally a regular maintenance inspection, concentrating on condenser and evaporator coil soiling will ensure the system operates efficiently and lasts longer. This is especially important during the summer when refrigeration systems struggle to cope with warmer temperatures and are often blocked by dust and dirt.	Cost £3,000 for 2 days consultancy Saving 20% refrigeration energy 77,670 kWh £6,200
Carry out thermal imaging survey of cold storage facilities	Some areas of condensation were observed inside the cold storage areas, this is indicative of insulation defects or thermal bridging. These problem areas are better identified with a thermal imaging survey which will highlight the extent of the problem. Other areas that could be checked are door surrounds, holes in walls for cabling and pipework, and seals between composite panels. Repair of problem areas will not only reduce energy consumption but will also help to maintain product quality.	Cost £3,500 for consultancy and repairs Saving 10% refrigeration energy 38,800 kWh £3,100
Fit automatic lighting controls in communal areas and in the packhouse	In buildings where there is no obvious individual responsibility for energy consumption, automatic controls should be installed. The following are suggestions that might be considered: Light level sensors for packhouse Occupancy sensors for mess rooms/canteens/changing facilities Dawn to dusk sensors for communal facilities lighting Time-switch override to ensure no lights are left on automatically out of hours	Cost £300 per control 15 controls – £4,500 Savings 10% lighting consumption – 5,100 kWh £408 per annum

Site D

This site is a mixed Brassica and Brussels sprout grower and packer. The packing facilities are old and have grown alongside the business to be a mixture of building types and ages.

	Detail	Cost/ benefit
Establish proper monitoring techniques for all energy consumption and analysis	It is important that energy data gathering and monitoring is carried out. The analysis of the energy data should be carried out regularly and informed decisions made with regards to efficiencies. Realistic energy saving targets should be set and reviewed on a regular basis	Cost £5,000 for time and monitoring equipment Saving 10% whole farm use 93,850 kWh worth £4,600 p.a
Repairs and maintenance generally on site and particularly in the coldstores.	Observed issues at the site included: Damaged insulation, badly fitting doors (and damaged seals), blocked condensers, blocked evaporators, dirty fans. All of these will contribute to unnecessary energy use and can be rectified for relatively little capital. There is a new packhouse in development which will fix many of the issues however if this is still in the planning stages then savings can still be made by targeting the issues above.	Cost £3,000 Saving 5% site electricity demand worth 3,105 kWh and £250 p.a
Match tractors to operations and spend time setting up equipment correctly	This could have the biggest immediate effect on energy consumption, by spending extra time ensuring tire pressures, ballasting and equipment settings are correct for the conditions and task will ensure the most efficient operation. Consider fuel efficiency when purchasing new machinery and include fuel consumption in the decision making process	Cost £5,000 time and setup Saving 5-10% at lower value worth 30,400 kWh red diesel and £1,215 p.a
Upgrade lighting	Currently fluorescent lighting is a mixture of T8 and T12 technology. More efficient lighting is T5 electronic ballast and can offer 40% reduction in consumption over T12 and 20% reduction in consumption over T8	Cost £40 per fitting Saving £5 per fitting per year
Focus efforts on the development of the new packhouse and cold store project	The best opportunity to ensure the most efficient practices is to consider it at design stage. Many of the recommendations in this action plan and the whole report should be considered in development of the new facility. Expert advice should be sought if required and will offer a different perspective to that of an installer. The new packhouse/coldstore complex should be much more energy efficient as well as offering produce quality improvements and labour efficiencies.	Indeterminate

Site E

This site grows, packs and stores bulb onions. Previously the site has undertaken an energy audit and implemented some of the recommendations.

	Detail	Cost/ benefit
Review recommendations in Carbon Trust energy survey and implement the actions where possible	A Carbon Trust survey was carried out at this site and a list of actions proposed to Site E. These actions should be reviewed and those not yet achieved should be properly investigated Specifically an energy management policy and individual responsibility for consumption at board level will ensure the best chance for savings to be made. Realistic targets should be set and regularly reviewed.	Cost £10,000 Saving estimated 10% whole site use 900,000 kWh and £52,000
Balance airflows in the onion stores	Suggestions of warmer areas in the onion store were made during the visit. Whilst the onion stores are generally well thought out and designed some attention to balancing airflows when the store has been loaded could help reduce energy consumption and improve crop quality in the problem areas. Balancing airflows will need to be done each and every season, as the pressures in the store will be different. A simple airflow meter can be purchased easily and will be necessary to achieve the best results.	Cost £1,000 Saving £0.13 per tonne stored
Carry out refrigeration efficiency inspections	COP monitoring is widely carried out in industry and resulting small changes in operation, refrigeration quantity and general maintenance can have big effects on efficiency without compromising system or produce cooling. Additionally a regular maintenance inspection, concentrating on condenser and evaporator coil soiling will ensure the system operates efficiently and lasts longer. This is especially important during the summer when refrigeration systems struggle to cope with warmer temperatures and are often blocked by dust and dirt.	Cost £500 for box store 5 alone Saving 20% refrigeration energy 10.000 kWh £800 for box store 5 alone
Consider renewable energy as LPG replacement	A significant quantity of LPG is consumed for curing the onions in the early stages of storage. With the advent of RHI it may be that using a renewable energy such as wood or straw could provide the required heat whilst reducing energy cost. This needs more in depth investigation and will be highly dependent on the structure of the scheme when it is announced late in 2011.	Requires further investigation
Fit fuel metering and keep fuel log for tractors	The information regarding diesel consumption in tractors is sketchy and does not lend itself to establishing efficiencies of particular tasks. Detailed information regarding consumptions and the conditions in which tasks were undertaken is key to being able to specify improvements. A simple log sheet recording fuel fill ups and the task carried out between fill ups is a good starting point. More advanced systems that automatically collect relevant data will give more useful information at increased cost.	Cost £5,000 No savings directly but 2-5% as a result of better information possible 2% is worth 77,234 kWh and £2,860 p.a.

Site F

This site grows and packs mixed Brassicas. Generally in good condition the actions reflect this.

	Detail	Cost/ benefit
Establish proper monitoring techniques for all energy consumption and analysis	It is important that energy data gathering and monitoring is carried out. The analysis of the energy data should be carried out regularly and informed decisions made with regards to efficiencies. Realistic energy saving targets should be set and reviewed on a regular basis	Cost £5,000 Saving estimated 10% whole site use 691,137 kWh £32,000
Carry out refrigeration efficiency inspections	COP monitoring is widely carried out in industry and resulting small changes in operation, refrigeration quantity and general maintenance can have big effects on efficiency without compromising system or produce cooling. Additionally a regular maintenance inspection, concentrating on condenser and evaporator coil soiling will ensure the system operates efficiently and lasts longer. This is especially important during the summer when refrigeration systems struggle to cope with warmer temperatures and are often blocked by dust and dirt.	Energy for refrigeration is indeterminate savings therefore 20% of energy use but further investigation required
Match tractors to operations and spend time setting up equipment correctly	This could have the biggest immediate effect on energy consumption, by spending extra time ensuring tire pressures, ballasting and equipment settings are correct for the conditions and task will ensure the most efficient operation. Consider fuel efficiency when purchasing new machinery and include fuel consumption in the decision making process	Cost £5,000 time and setup Saving 2–5% at lower value worth 59,945 kWh red diesel and £2,381 p.a.
Upgrade lighting	Currently fluorescent lighting is a mixture of T8 and T12 technology. More efficient lighting is T5 electronic ballast and can offer 40% reduction in consumption over T12 and 20% reduction in consumption over T8. Also install automatic controls on lighting systems and investigate if lower light levels can be used in coldstores.	Cost £40 per fitting Saving £5 per fitting per year

Appendix Two - Top Ten Tips for energy saving in field vegetable enterprises

The following guidelines should be used as the starting point for implementing energy efficiency on a field vegetable enterprise.

Monitor your energy use and track consumption against production / output levels. Where appropriate break down to individual fuel types and / or end uses (e.g. kWh/tonne stored, kWh/mm irrigation water applied etc). Use the data you collect to set realistic but challenging improvement targets for the future.

Implement a simple turn it off / close it / turn it down campaign. Communicate the importance of energy saving to all your staff.

Check the insulation and sealing of your crop stores / cold rooms etc. Repair any damaged insulation, door seals etc and close of gaps around pipe or cable entry points etc. If current insulation standards do not achieve the current minimum requirements (typically a U value of between 0.3 and 0.4 $W/m^2/^oC$) install some upgraded insulation.

Check, clean and maintain all fans, ducts, air distribution components etc.

Calibrate control sensors, place sensors in the best position for taking accurate readings and check the function of store controls.

Maintain refrigeration equipment regularly; pay particular attention to refrigerant levels and the airflow over the evaporator and condenser coils. When making refrigeration equipment purchases ensure that new equipment uses advanced capacity control technologies such as variable speed drive compressors, electronic expansion valves and floating heat pressure control.

Clean lights regularly (including both the bulb and the fitting). When repairing or upgrading lights consider upgrading to the energy efficient option including electronic fluorescents, discharge lights or even LED's.

Match tractor and implement combinations for optimum output. Pay particular attention to the detailed points including maintenance, tyre pressure setting and ballasting.

Repair water leaks in irrigation pipes and carefully control pump settings and operation. Consider installing variable speed drives on pump sets.

Use simple automatic controls such as time switches, occupancy sensors and thermostats on energy consuming equipment in worker facilities.

Appendix Three - Financial incentives for energy efficiency & renewable energy

Energy efficiency

Grants

In some areas of the country grants have been available for upgrading equipment to high levels of energy efficiency through bespoke support through Regional Development Agencies. Farmers intending to make investments in the area of energy efficiency would do well to contact their RDA.

Loans schemes

Loans of between £3,000 and £25,000 have been available to agriculture through the Carbon Trust for energy efficiency projects which meet certain carbon saving criteria. Loans have been provided over a period of four years. This scheme has provided support on the basis that capital is repaid using the savings made from installing new energy saving equipment.

An announcement on 4th March 2011 indicated that the scheme guidelines are set to change with the introduction of a 'green finance deal' with £550m backing from Siemens Financial Services . No further details of project eligibility or the terms the finance is available at the time of writing this report. For up to date details go to www.carbontrust.co.uk/loans .

Enhanced capital allowances

Certain energy efficiency upgrades can qualify for enhanced capital allowances (ECAs) within the Revenue and Customs rules. ECAs allow 100% of the value of the upgrade to be written off against tax in the first year of investment. Qualifying equipment is listed on the ECA scheme technology list website www.ECA.gov.uk

Key Features of the ECA scheme

- Open to all businesses that pay UK corporation or income tax, regardless of size, sector or location.
- Provides 100% first-year capital allowances on investments in energy-saving equipment against taxable profits of the period of investment.
- Only spending on new and unused energy-saving equipment can qualify for ECAs.

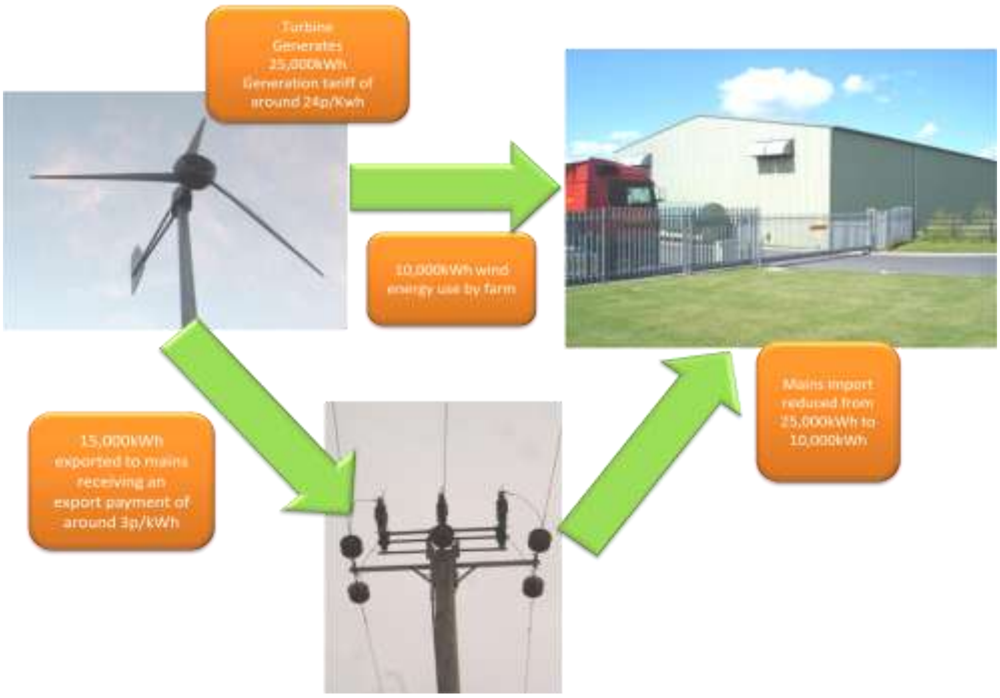
- Capital allowances are available for spending “on the provision of” plant and machinery. This can include certain costs arising as a direct result of the installation of qualifying plant and machinery such as; transport of the equipment to the site, and some direct installation costs.

Renewable electricity

Renewable energy installations which generate electricity including wind, solar, hydro, and anaerobic digestion are supported through the Feed-in tariff system which was introduced in April 2010. Feed-in tariffs provide support in terms of a ‘tariff’ payment associated with the amount of electricity generated rather than giving capital grants.

Basically the system consists of a **generation tariff** - an amount paid for each kWh of energy generated irrespective of whether it is used on the site or is exported and a minimum **export** tariff – a guaranteed payment for each kWh exported to the grid (this may be increased by adopting a separately negotiated power purchase agreement). The generation tariff value is specific to the technology used and the size of the equipment. Tariff payments are indexed linked and have a lifetime of between 10 and 25 years depending on the technology. Clearly, where energy is provided by the renewable resource to the farm itself, this displaces the use of bought-in grid energy, and the associated saving is at the equivalent purchase price.

An example based on an 11 kW wind turbine is set out below:



Typical tariff rates for different technologies and sizes of equipment are set out below:

Technology	Scale	Tariff level for new installations in period (p/kWh) [NB tariffs will be inflated annually]			Tariff lifetime (years)
		Year 1: 1/4/10 – 31/3/11	Year 2: 1/4/11 – 31/3/12	Year 3: 1/4/12 – 31/3/13	
Anaerobic digestion	≤500kW	11.5	11.5	11.5	20
Anaerobic digestion	>500kW	9.0	9.0	9.0	20
Hydro	≤15 kW	19.9	19.9	19.9	20
Hydro	>15-100 kW	17.8	17.8	17.8	20
Hydro	>100 kW-2 MW	11.0	11.0	11.0	20
Hydro	>2 MW – 5 MW	4.5	4.5	4.5	20
MicroCHP pilot*	<2 kW*	10*	10*	10*	10*
PV	≤4 kW (new build)	36.1	36.1	33.0	25
PV	≤4 kW (retrofit)	41.3	41.3	37.8	25
PV	>4-10 kW	36.1	36.1	33.0	25
PV	>10-100 kW	31.4	31.4	28.7	25
PV	>100kW-5MW	29.3	29.3	26.8	25
PV	Stand alone system	29.3	29.3	26.8	25
Wind	≤1.5kW	34.5	34.5	32.6	20
Wind	>1.5-15kW	26.7	26.7	25.5	20
Wind	>15-100kW	24.1	24.1	23.0	20
Wind	>100-500kW	18.8	18.8	18.8	20
Wind	>500kW-1.5MW	9.4	9.4	9.4	20
Wind	>1.5MW-5MW	4.5	4.5	4.5	20
Existing microgenerators transferred from the RO		9	9.0	9.0	to 2027

Renewable heat

It is stated Government policy that a support system for renewable heat installations will be introduced in 2011. This is to be called the Renewable Heat Incentive or RHI. RHI will work in a similar way to the Feed-in tariff, in that it will provide a payment for every kWh of energy supplied by particular renewable heat technologies. Technologies included will be; solid biomass, bioliquids, ground and air source heat pumps, and solar thermal panels.

Indicative support rates were published in the early consultation and these are set out below

Technology	Scale	Tariff rate (p/kWh)	Tariff lifetime (years)
Solid biomass	Up to 40 kW	9	15
Bioliquids	Up to 45 kW	6.5	15
Biogas on site combustion	Up to 45 kW	5.5	15
Ground source heat pumps	Up to 45 kW	7	23
Air source heat pumps	Up to 45 kW	7.5	18
Solar thermal	Up to 20 kW	18	20