Farm
Advisory
Service

Renewable Energy

The Farm Management Handbook

The UK reference for farm business management

SAC CONSULTING

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Introduction

Fluctuating energy costs, government initiatives, a desire for self-efficiency and reducing your carbon footprint have prompted many farmers to consider renewable energy, as well as assessing where energy efficiency savings can be made. Successful small and medium scale renewable developments will make the best use and get the most value out of renewable generation. Energy savings are now often the driving factor for many farm scale renewable projects. This section introduces some renewable energy technologies that are most relevant to the rural sector: wind, hydro, anaerobic digestion, biomass heating, ground source heat pumps, biodiesel and energy crops. Landowners pursuing renewable energy projects are advised to seek independent advice to verify likely energy yields, costs and technical and economic viability, rather than rely solely on information supplied by equipment manufacturers. Consideration of local planning policy and environmental impact, alongside suitable engineering, construction and design scrutiny should be undertaken for any renewable development.

Energy efficiency

Before considering installing any renewable energy generation technologies it makes sense to review what opportunities there may be to improve energy efficiency. Undertaking an energy audit helps to identify energy uses and highlight potential opportunities to reduce energy bills as well as to improve your business's carbon footprint (see Carbon section for more detail on carbon foot printing). The first step in reducing energy use is to measure current usage levels to set a baseline. This can be measured by taking meter readings or by using figures from business trading accounts. Using more regular physical and financial records will provide greater detail and understanding of energy uses. Comparing the level of energy used in subsequent years against the baseline figure will then give an idea of trends in energy consumption. Sources of energy inefficiency can then be identified and addressed, both in terms of technical solutions and management changes.

Increasing power efficiency, managing voltage and making the best use of your existing grid connection are all important steps to consider before investing in renewables. Getting these things right and optimising your existing systems can help save you money and make sure you are investing in the right scale and type of renewable technology or storage options available.

Benchmarking energy use against other similar farms can also highlight where improvements can be made. There can be differences in energy use of 30% or more with comparable businesses. The greatest savings in energy use will come from changes to farming systems and practices, therefore agricultural knowledge is vital to be able to exploit these potential savings.

Renewables options appraisal

Each renewable energy technology has different characteristics, which will influence whether or not it is suited for use on a particular farm. It is vital to carefully consider what your objectives are and what you want from a renewable energy installation at an early stage. The following factors are important to consider before deciding which renewable energy technology option(s) you wish to investigate:

- What is the scale and pattern of your energy demand?
- What energy resources do you have available on your farm?
- How much capital do you have access to for investment?
- What level of risk are you willing to take?

For general information on energy efficiency and renewables see:

- FAS Renewable Energy (www.fas.scot/environment/climate-change/renewable-energy)
- Energy Savings Trust (www.energysavingtrust.org.uk)
- Carbon Trust (www.carbontrust.com)
- Scottish Renewables (www.scottishrenewables.com)
- Renewable Energy Association (www.r-e-a.net)
- Business Energy Scotland (https://businessenergyscotland.org)
- Home Energy Scotland (www.homeenergyscotland.org)
- Local Energy Scotland (https://localenergy.scot)

Grants, incentives and income options

Incentive schemes for renewable energy projects were the main driver for development during the early days of the technology. As renewable technologies advanced, the lower cost of the technology and the savings from offsetting energy bills, and other payment options, made appropriately designed small and medium scale renewable projects an economically viable option, without incentive payments and government subsidies. Impartial advice is recommended to help explore all the various options available when considering renewable developments.

It is always recommended to keep up to date with the latest policies and government announcements, as future opportunities may arise. For example, during summer 2024 the new UK Government announced an Energy Independence Bill, including the creation of Great British Energy, which will support renewable projects across the UK. Other measures announced include the scaling up of renewables, speeding up planning and grid connection processes for energy generators and more investment on energy efficiency measures.

As the technology has established, less government funding support has been required. Banks and financial companies continue to offer support and favourable loans and funding options for a range of renewable developments and for any developer it is worth exploring these options.

Using renewables to offset your own energy demand, therefore, reduce your energy bills is often the best option, especially during energy price hikes and a fluctuating energy market. If you have a high onsite demand that matches well with renewable generation, then it is worth considering your options to offset these high energy bills.

Power purchase agreements (PPA) and export price tariffs provide additional options for generating revenue. However, there can be conditions such as minimum capacity requirements, and the payments can vary widely, therefore, it is beneficial to shop around to find the best offer.

The Smart Export Guarantee (SEG) enables generators to be paid for electricity exported to the grid. SEG is an obligation set by the government for licensed electricity suppliers to offer a tariff and make payment to small-scale low-carbon generators for electricity exported to the National Grid, if they can meet certain criteria. The SEG rate is determined by the various licensees.

Renting land to renewable developers is another option commonly seen on farms as a way of generating income. The amount of land they need varies depending on requirements, but they usually want areas with a high potential yield, good access to the grid and non-prime and non-peaty land. Rental agreements will vary, therefore it is beneficial to get the best deal and get terms checked by a solicitor, as your land will be tied up for the duration of the contract. The change of land from agriculture to energy can have payment and tax implications, and issues such as land access and decommissioning need to be agreed.

There has been a mix of different support mechanisms over the years for different types and scale of renewable generation, including the Renewable Heat Incentive (RHI), Renewable Obligation Certificates (ROCs), and Contracts for Difference (CfDs). More information on all current and past government schemes can be found at:
www.ofgem.gov.uk/environmental-and-social-schemes

Support for biofuels is provided by the Renewable Transport Fuels Obligation (RTFO). The RTFO came into effect on 15 April 2008 and aims to increase the use of renewable fuels in the UK and cut the reliance on imported diesel.

A consultation titled; *Amending the Renewable Transport Fuels Obligation (RTFO) to increase carbon savings on land, air and at sea* was undertaken in 2021. It proposes:

- increasing the main RTFO target to supply renewable fuels from 9.6% to 14.6% by 2032;
- expanding RTFO support to new transport modes such as renewable hydrogen in rail and maritime;
- implementing updated sustainability criteria.

For further information on the RTFO please see:
www.gov.uk/guidance/renewable-transport-fuels-obligation

Batteries and storage

There is ever increasing interest and demand to couple renewable energy projects with battery technology or some other form of storage. This can have the advantage of making better use of your renewable technology, increasing yields and reducing the intermittency issues faced by renewable generation. The advancement of electric vehicles and increasing demand for grid balancing services provide additional opportunities in this area.

Storage technologies that can be appropriately deployed at a farm scale include batteries, heat storage and hydrogen production. The market is continuing to grow, bringing a wider range of options available to farmers. A range of revenue streams can be accessed by storage operators including reduced energy import costs, the ability to trade electricity at more attractive price points and receipt of payments for providing grid balancing services.

It is recommended anyone considering these options explores the full range of storage technologies available and gets independent advice from a reputable source. Careful financial analysis and system design is needed, alongside an assessment of onsite demands and export opportunities to ensure storage options are viable.

Wind power

On-farm wind power has two main scales of operation to consider, with commercial wind farm sites having a focus on exporting power to the grid, while small to medium scale generation is more concerned with offsetting purchased power within the farm business. Even if the power generated is primarily being used on the farm, demand may not always be constant, therefore, it is likely that a proportion of the power produced will have to be sold to the grid at certain times.

For landowners with suitable sites for large-scale wind developments there are several development options available:

- Allow a developer to install the turbine(s) in exchange for an annual payment;
- Install the turbine(s) independently either by self-funding or using bank finance, or any combination of the two;
- Joint venture scheme with developer or neighbour;
- Community project with local buy-in.

Wind turbines

Wind turbines are best located in exposed areas with open fetch especially in the direction of the prevailing wind, away from residencies, though situated as close as possible to a grid connection and with good road access. Farmland is often ideal because the total footprint of a turbine development is relatively small and does not lead to a significant loss of agricultural land.

Larger wind turbines take advantage of the higher wind speeds that exist at greater altitude and so are more efficient and economic, however, they also require a larger capital investment.

When comparing the potential benefits of wind power, it is important to be able to compare like with like, therefore, an understanding of the following terms is key:

Rated power - The maximum power that can be produced when the turbine is operating within its safety limits. It is quoted in kW, which is a measure of the energy produced per second.

Theoretical power production - Rated power x number of hours of production per day x number of days operation per year: 500 kW x 24 hrs x 365 days = 4,380,000 kWh.

Capacity factor - Wind is not always blowing at a speed sufficient to spin the turbine and generate power, therefore, the capacity factor refers to the percentage of the total available time that the turbine is actually generating power, e.g. 30%.

Actual power production per year - Theoretical power x capacity factor: 4,380,000 kWh x 30% = 1,314,000 kWh.

The actual power produced will depend on the average wind speed in the area and other factors such as the height of the turbine, diameter of the rotor and the proximity of any feature that shelters the turbine or creates turbulence such as buildings, trees, walls, and the like.

Hydro power

Small-scale run-of-river hydro schemes can be a viable source of renewable electricity on a suitable site.

The key factors that determine the power produced by a hydro scheme are:

Head - The vertical distance through which the water will fall.

Flow Rate - The quantity of water that will be available for power production.

Developers of hydropower schemes require a water use licence from Scottish Environment Protection Agency (SEPA) who will seek to ensure a balance between the benefits to renewable energy generation and the adverse impacts on the water environment. Schemes where the fall in the river between the intake and discharge points has a gradient of 1 in 10 or steeper will be more likely to obtain a water use licence.

Civil engineering costs vary greatly from site to site. Development costs for very small schemes are much higher per kW capacity than larger schemes. Small sites where the available head is 3 m or less are unlikely to provide a reasonable return on investment unless existing infrastructure can be utilised to reduce capital cost. Higher head schemes need lower flows and hence smaller and cheaper equipment to generate the same power as low head schemes.

The flow rate will vary during the year, however, for a scheme to be viable there must be sufficient flow to keep the system operating at near its rated power for a large proportion of the time. Some flow must be left in the stream for environmental sustainability and consideration of the needs of migrating fish is important.

An indication of the power production of a scheme can be obtained from the following equation:

Power produced (kW) = 7 x Flow rate (m^3/s) x Head (m)

A capacity factor of 50% can be expected where a scheme is sized on the mean flow of the river, therefore, a 10 kW scheme may have an annual output of approximately 43,800 kWh, which is sufficient for about 10 houses.

Further information can be obtained from British Hydropower Association (www.british-hydro.org).

Solar photovoltaics (PV)

The sun's energy has always been used by farmers for growing and drying crops. Solar photovoltaic (PV) panels, which produce electricity from sunlight, have become an increasingly common sight on farms in recent years. Despite the comparatively low solar insolation levels in Scotland when compared to the south of England, solar PV can still be a viable option north of the border.

PV panels can be either roof or ground-mounted. Roof mounted arrays are more efficient in terms of land use because they make use of an existing area of space that is not currently adding value to a farm business. Farms also commonly have large areas of roof available in the form of barns and sheds, although it is important to check that roofs are strong enough to support a system if retrofitting to an existing structure. Another issue is that roofs do not always face in the optimum direction (south) or at the optimum angle (usually around 30-40 degrees) and may be shaded by other structures, and in these cases ground-mounted arrays can be an alternative option.

Ground mounting allows for the ideal positioning of panels, which maximises the efficiency of a scheme. However, it can also mean that land use is diverted away from food production and into energy production and there can be additional planning considerations. Land around the panels can still be used for small-scale livestock. The panels are mounted on a framework at a height that allows animals to graze and forage beneath them without damaging or compromising the operation of the system. Advice on the impacts of installing ground mounted solar panels on area based agricultural subsidy payments should be taken.

Biomass heating

Biomass boilers are a well proven, efficient and reliable technology that has been developed over many years in countries such as Austria and Germany. These boilers are generally technologically advanced and highly efficient. More basic boilers are available, which are less efficient and have very little automation, and consequently come at a significantly lower capital cost.

There are four main types of biomass boiler: woodchip boilers, pellet boilers, log boilers and straw boilers. All four options have pros and cons and care must be taken to ensure the right type of system is selected to match user requirements, including factors such as the degree of automation required, the scale and patterns of heat demand, capital cost and local fuel costs and availability.

A few key facts about different woodfuel options include:

- Woodchip and pellet boilers can be fully automated.
- Log and straw boilers can be an economic option where farms have their own log or straw supply. However, they must be loaded manually, generally on a daily basis as a minimum.
- Woodchip is a lower cost fuel when compared to pellets, however, is bulky and can be difficult to handle.
- Wood pellets are clean, easier to handle, require less space to store and have a higher energy output. They are more expensive than chip and cannot be produced on-farm. However, the capital cost of a pellet boiler is lower than a chip boiler.
- Woodchip boilers and their fuel supply systems have higher capital costs, and for technical reasons they are generally not suited to smaller, domestic applications (e.g. below 50 kW).

Costs for biomass boilers are highly variable depending on the individual system requirements. There may also be significant costs associated with installations such as constructing a fuel store, or purchasing specialist vehicles to use for handling or loading fuel, etc.

In most small-scale situations, it is not practical to produce electrical power from biomass, because such systems are complex and expensive.

For this reason, generating power is only worth considering when there is a large demand for both heat and power.

Farm scale biodiesel

Biodiesel can be made from a wide range of vegetable oils and animal fats (tallow). High quality straight vegetable oil (SVO) can also be used as a fuel at higher inclusion rates in certain engines. The use of biodiesel and SVO above 5% inclusion could impact on engine manufacturer's warranties.

On-farm biodiesel production from rapeseed involves two stages; cleaning and crushing the seed to extract oil, and esterification of the oil by mixing with methanol in the presence of a catalyst to remove glycerol. Although chemically this is a simple process there is a need for careful quality control to achieve the required standards. Handling methanol and the catalyst (usually potassium hydroxide) on the farm is hazardous and requires attention to health and safety and insurance. To produce SVO is the same as for biodiesel without the esterification reaction step. Rapeseed meal is an important co-product of the crushing process and a useful protein supplement for animal feed.

Growers should calculate an 'on the road' price considering the costs of feedstock, capital and operating costs, allowing for income from production of rapeseed meal, and adding the full fuel duty and VAT. Small-scale producers may benefit from a 2,500-litre tax free personal allowance. Production costs for SVO are considerably lower.

Renewable Transport Fuel Obligation (RTFO) Certificates offer the potential for increased returns, however, it may prove difficult for smaller operators to access this income. Biodiesel from waste materials such as tallow receive double RTFC's. Data on carbon and sustainability performance must be independently verified before RTFCs are awarded.

Anaerobic Digestion

Anaerobic digestion (AD) uses bacteria to convert organic matter into methane and carbon dioxide (referred to as "biogas"), in the absence of oxygen. The biogas can be used to provide heat, generate electricity or upgraded to biomethane (carbon dioxide is removed) for injection into the gas grid. In addition, AD can provide other benefits; utilising wastes, reducing emissions of methane, cutting odours and enhancing water quality.

Feedstock can be any biodegradable non woody plant, animal matter (manures/slurry), energy crops (grass, rye or maize silage, beet) and food waste. Food wastes are becoming less attractive due to falling gate fees for accepting them, complex licensing and regulation and higher capital costs of the plant for pasteurisation. However, sustainability requirements that 50% of biogas must be derived from wastes or residues has the potential to open up new markets for AD, so long as the waste material is responsibly sourced and suitable for AD. It is important that the mix is kept relatively consistent and that the balance of carbon to nitrogen is suitable for the bacteria. Feedstock can comprise conventional grass silage, however, specialised energy crops are likely to perform better overall in an AD plant, as they are not selected for feed quality, just dry matter yield and nitrogen efficiency.

The high degree of automation and control in a modern biogas plant means that on-farm plant costs are high. For any proposed plant, the cost and availability of feed stock will be the main factors determining viability. If you do not have enough of your own land available to produce sufficient feedstock, securing long term contracts for off-farm feedstocks will be essential. A thorough feasibility study is also recommended to assess the viability of any project being considered.

For larger scale AD plants, whether gas–to-grid or Combined Heat and Power, farmers are mainly involved as feedstock suppliers. The capital costs of gas-injection plants are higher due to the need to “scrub” the gas to meet grid standards (remove carbon dioxide). The location of these plants is also usually dependent on local gas grid capacity. Where feasible, gas to grid AD plants have a clear economic advantage, and this is reflected in the increasing number of new plants following this approach. For farmers supplying feedstock the principles are the same though there may be greater seasonality of pricing in gas to grid plant reflecting payment structures for wholesale gas (higher prices in the winter).

Farmers growing crops for AD feedstock will find that prices vary from plant to plant and will reflect the basis of the sale; standing crop or delivered plant. Prices will also reflect shared costs such as specialist machinery and the value assigned to digestate.

The relative profitability of AD and cereal crops will change from year to year and that is why AD crops are best included as part of range of crops and market outlets. AD plant operators are unique in offering relatively long contracts of 5 to 10 years for feedstock crops. Therefore, the best approach for most farmers is likely to be to include AD crops as part of mixed cropping system. This will deliver some security of income from long term AD contracts alongside flexibility to benefit from any rise in grain prices that may occur.

AD crops may also offer other potential benefits to the farm business including; spreading the workload, providing early entry for oilseed rape and enabling grass to be brought back profitably to all-arable rotations.

Farmers growing AD feedstock must now meet key sustainability standards to receive support. Ofgem require all RHI claimants to demonstrate their feedstocks meet sustainability criteria regarding land use change (rarely relevant in UK) and carbon emissions. For the RHI the carbon intensity of the feedstock must be less than 34.8g CO_2 equivalent per MJ of energy produced, however, for new biomethane plants operating within the Green Gas Support Scheme the threshold is reduced to 24g CO_2 equivalent per MJ energy. In crop production the main source of greenhouse gases is inorganic nitrogen fertiliser, so usage needs to be minimised. In AD systems this is partly achieved by the application of digestate back to the crop. With careful planning it is likely that most crops grown for AD will be able to meet these carbon targets. Ofgem provide an online calculator and guidance though it is advised that expert advice is also sought when preparing this information especially for the first time. See www.ofgem.gov.uk for full details.

Crop Costs for Anaerobic Digestion

PHYSICAL DATA

(a) Yield and harvest

Yields are based on crops grown in southern and central Scotland assuming average weather conditions and SRUC's experience from recent trials. Actual yields will vary widely and are much less certain in the north with maize not recommended outwith southwest Scotland. Trial results indicate that rye yields are more consistent year to year than beet, reflecting the crop's longer growing period. Harvest of winter hybrid rye is typically around the middle to end of July with maize and energy beet harvests in late October.

(b) Seed

Certified seed has been assumed for all crops and hybrid seed for rye and maize.

(c) Fertiliser

Full rates of artificial fertiliser have been calculated to match crop offtake. Where digestate from an Anaerobic Digestion (AD) plant is applied fertiliser rates should be adjusted accordingly. In practice digestate use is likely to reduce but not entirely replace the requirement for artificial fertiliser due to mismatches in nutrient availability and timing between crops.

(d) Sprays

Full rates based on current best practice have been assumed.

(e) Contract

These include the cost of specialist contractors for harvesting and transporting the roots or silage produced to a nearby (within 3 miles) AD plant. Transport costs should be adjusted accordingly to the distances involved.

(f) Output prices

The price in the market for AD feedstock will be determined by local feedstock supply and demand issues and the conditions of the contract. The contract price will reflect the basis of the sale; standing crop, ex-farm or delivered to plant. It will also reflect the method agreed to share other costs such as specialist machinery and the value and costs assigned to any digestate applied to the land (see previous pages).

Crop Costs for Anaerobic Digestion

COST OF PRODUCTION DATA - LOCAL DELIVERED BASIS

	Energy beet	Hybrid rye	Grass silage	Maize
Yield: fresh (t/ha)	67.5	42.0	36.0	38.0
Dry matter (%)	22%	34%	29%	30%
Yield : dry matter (t/ha)	14.85	14.28	10.44	11.40
Methane yield (m^3/fresh t)	99	108	95	106
Energy (MWhr TH/fresh t)	1.2	1.3	1.1	1.3
Energy (MWhr TH/ha)	79.7	54.1	40.9	48.0
		£/ha		
COSTS				
Seeds	202	162	28	196
Fertiliser	230	328	381	275
Sprays	224	37	10	91
Contract cultivation	346	277	66	305
Contract harvesting	388	178	434	173
TOTAL COSTS (£/ha)	1,390	982	919	1,040
TOTAL COSTS (£/t)	21	23	26	27
TOTAL COSTS (£/MWhr TH)	17	18	22	22

Note: Contract costs include fuel. The above cost of production data exclude charges such as land rental, interest, management time and any margin requirements which will be important to include when considering any contract price agreement.

Biomass Crops for Energy

Willow short rotation coppice

Willow is a perennial biomass crop grown principally for energy production on a 15 to 20 year rotation with harvesting every 3 to 4 years once established. Returns from the crop are highly dependent on yield and woodchip price. The main market for the woodchip is on contract to power generators and large-scale thermal plants. The woodchip is not suitable for small-scale biomass heating schemes without significant grading and drying costs due to the high bark and moisture content and oversized chips. Given the limited markets, high costs of establishment, variable growth rates and lack of planting grants the crop is largely uneconomic.

Short rotation forestry

This is a variation on conventional forestry based on early harvesting of fast-growing species through coppicing and regrowth. In general, the most economic age to harvest conventional timber species is at maturity so the case for shorter rotations in most species remains unproven. A number of tree species capable of coppicing can be used for short rotation forestry (SRF), e.g. Alder, Notofagus, Poplar, Eucalyptus and Sycamore. Large- scale trials with several species and sites are currently being carried out by the Forestry Commission. As with conventional forestry, a wide range of sites will be suitable for cultivation of these species, including sites which have a lower nutrient status and a poorer land classification.

Trees are grown to butt size 15-20 cm for harvest at 8-20 years. Current advice is to plant at 2m square and apply broad spectrum herbicide to control weeds during establishment. Nitrogen application in the first year should be avoided as there is no benefit to growth. SRF has not been examined on a sufficiently extensive scale or period to derive crop data as yet. Yields will vary from site to site, with average annual increments estimated at between 4 to 9 m^3/ha/yr or around 1.5 to 3.2 ODT/yr. Planting grants may be available as part of the forestry grant schemes being offered under Rural Development across the UK. See the Scottish Forestry (https://forestry.gov.scot/) for updates on the energy forestry trials work underway.

Miscanthus

Miscanthus is a perennial energy crop suited to the southern half of the UK with viability dependent on yields, contract prices and proximity to biomass power stations or other market outlets. The crop has also found a higher value outlet as poultry and horse bedding due to its high level of moisture absorbency and low dust levels. The miscanthus chips are also less favoured than woodchips for fuel due to low bulk density and high chlorine content. As a result, growing the crop for bedding is becoming the preferred end use in many areas. The crop uses a C4 photosynthetic pathway, like maize, requiring high light intensities and temperatures.

Yields at suitable sites south of a line from the Severn to the Wash are expected to be 12-15 ODT/ha. Low ground sites north of this may also be feasible but as with maize, yields and viability are likely to be reduced.

The crop is established using rhizomes, typically at 15,000 plants/ha. Like willow coppice, planting requires specialist equipment and relatively costly planting material resulting in high establishment costs. After the first year the crop can be harvested annually and has a useful life of 15-20 years. Weed control is necessary in the establishment year and possibly in the first spring. Nutrient demand is low with typically an application of 40N:40P:40K kg/ha in year one. Most crops are unlikely to require further applications although up to 150 kg/ha N may be applied over the first 2 years in some situations. The need for pest and disease control is low.

Reed canary grass

Reed canary grass is a perennial plant well suited to cultivation in northern and western parts of the UK and commonly grown in Scandinavia for fodder and increasingly for AD. In the UK the plant is widely used as a game cover crop. It grows well under marginal conditions, including upland areas and brownfield sites in northern and western areas. It is a perennial crop established from seed (unlike Miscanthus) leading to considerable cost advantages.

Establishment and cultivation are undertaken with existing farm equipment with the need for some nitrogen fertiliser to achieve maximum yield. Trial yields vary from 5 to 14 ODT/ha with the crop performing better at more northern sites where average yields of over 10 ODT/ha have been achieved. Further work is needed to determine viability, but it has cost saving and land use flexibility advantages compared to other perennial crops and can utilise more marginal land. The crop also has useful flexibility in its end use; in the summer it can be cut for AD production or grazed by cattle; in the winter and spring it can be baled for biomass fuel or animal bedding.