Farm Scale Renewable Energy Guide

Farm Advisory Service

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Contents

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Please contact the FAS National advice facility on 0300 323 0161 or email advice@fas.scot for more information.

Scotland's Energy Strategy and Just Transition Plan

In 2023 Scotland published its draft Energy Strategy and Just Transition Plan, along with a consultation process to inform the development of the policy. Throughout this proposal are a range of measures and targets to scale up renewable output, decarbonise our energy use, develop job opportunities and to reduce overall energy demand. It also includes plans to develop hydrogen, transition away from fossil fuel industries and expand community ownership.

"Our vision is that by 2045, Scotland will have a climate-friendly energy system that delivers affordable, resilient and clean energy supplies for Scotland's households, communities and business."

As part of this, the plan provides actions to support the decarbonisation of energy in the agricultural sector. The vision for Scottish agriculture will provide advice and support to help farmers and crofters reduce energy demand and decarbonise energy use though a suite of advice programmes, with ambition to reduce overall energy use in agriculture and to maximise opportunities for land managers for generating zero carbon energy.

This aligns with "Our Vision for Agriculture" published in March 2022 that outlines the Scottish Government's aim to transform how they support farming and food production in Scotland to become a global leader in sustainable and regenerative agriculture.

Did you know?

Agricultural energy use (including agricultural vehicles and processes) accounts for 0.8 MtCO2e, 2 % of Scotland's total emissions.

Approximately 300 million litres of (red) diesel (equivalent to 3 TWh) is consumed each year by the agriculture sector in Scotland (over 10% of Scotland's total estimated diesel consumption).

For further information and the latest updates on Scotland's Energy Strategy and Just Transition Plan, see: https://www.gov.scot/publications/draft-energy-strategy-transition-plan/

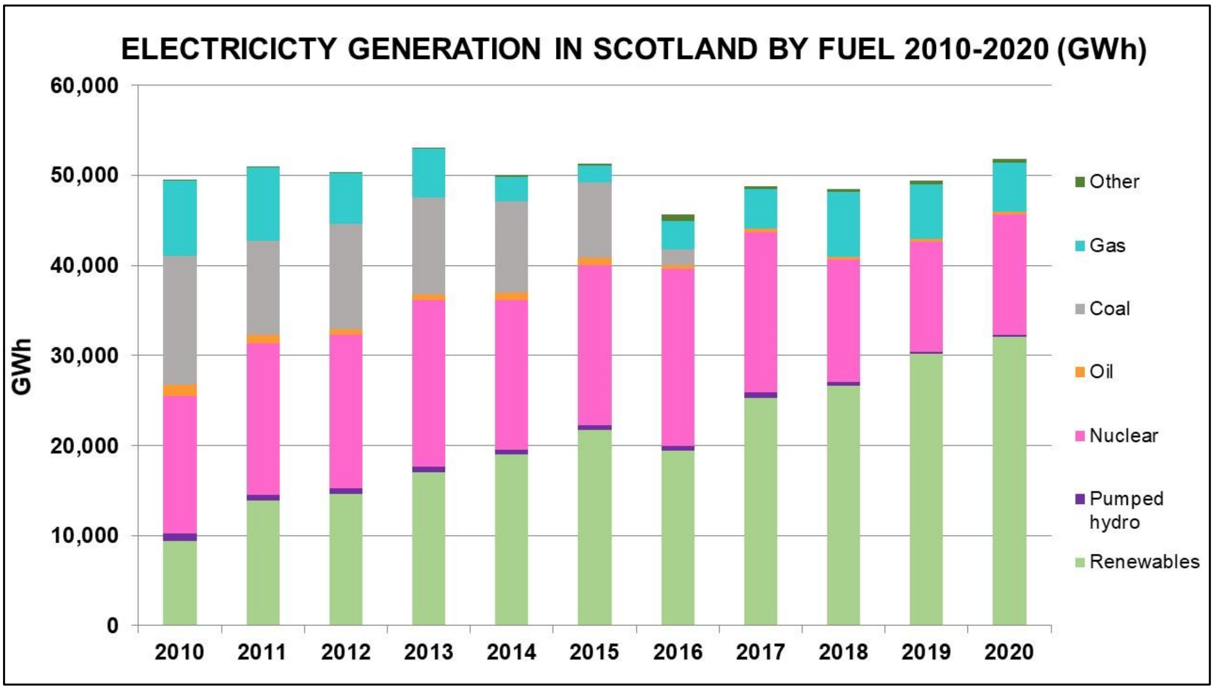
For the statement on sustainable and regenerative farming – next steps, see: https://www.gov.scot/publications/next-step-delivering-vision-scotland-leader-sustainable-regenerative-farming/

For more information and case studies on ways to cut carbon, increase sustainability and move towards net-zero visit: www.farmingforabetterclimate.org

Renewable energy targets and sector growth

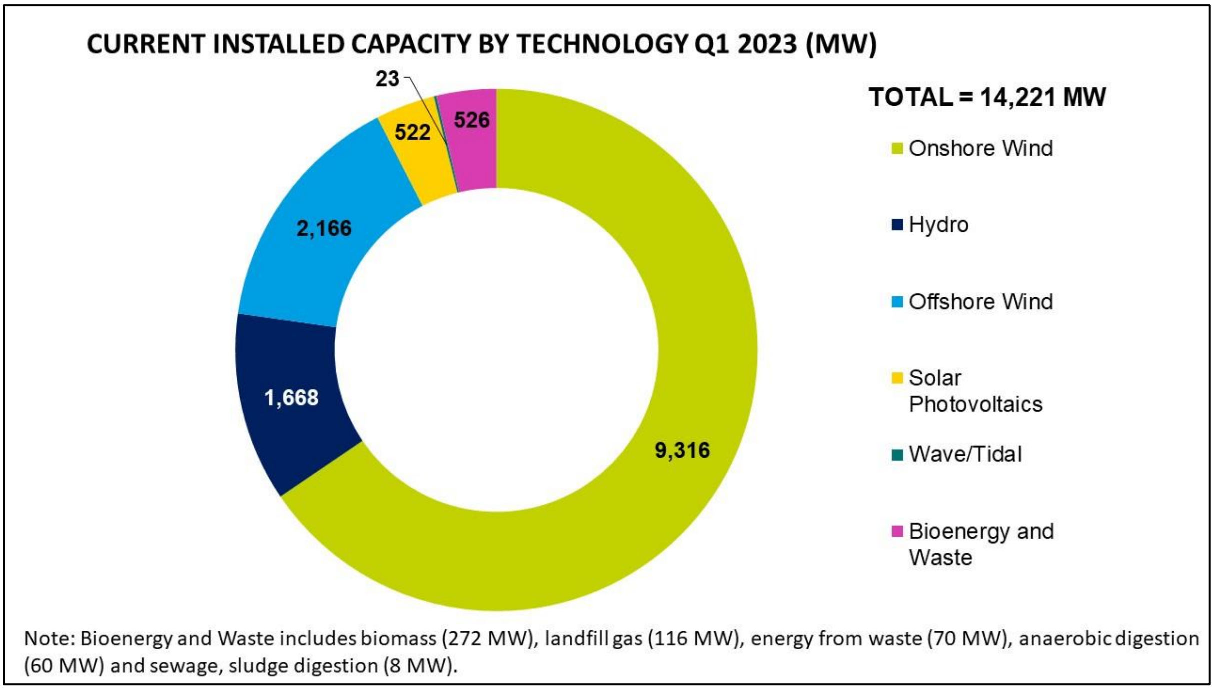
Scotland has made significant progress towards its renewable energy targets. In 2020, 26.7% of all energy consumed in Scotland was generated from renewable sources including home heating and transport emissions, with a target of achieving 50% by 2030[1]. Renewable electricity generation is now equivalent to approximately 97% of Scotland's gross electricity consumption, with targets to achieve 100%. Efforts are now also focussing on increasing the amount of heat we get from renewable sources, developing sustainable transport and lowering overall energy consumption.

Fossil fuels still contribute a large proportion of meeting our overall energy needs, especially natural gas and oil, and it is a challenge to move away from these to more sustainable sources. Coal, one of the highest greenhouse gas emitting fuels, has seen a large decline in Scotland, with renewable output increasing to help fill this gap. The chart below[2] shows the proportion of electricity generation each year from all sources, as well as the steady increase of renewables in the mix.

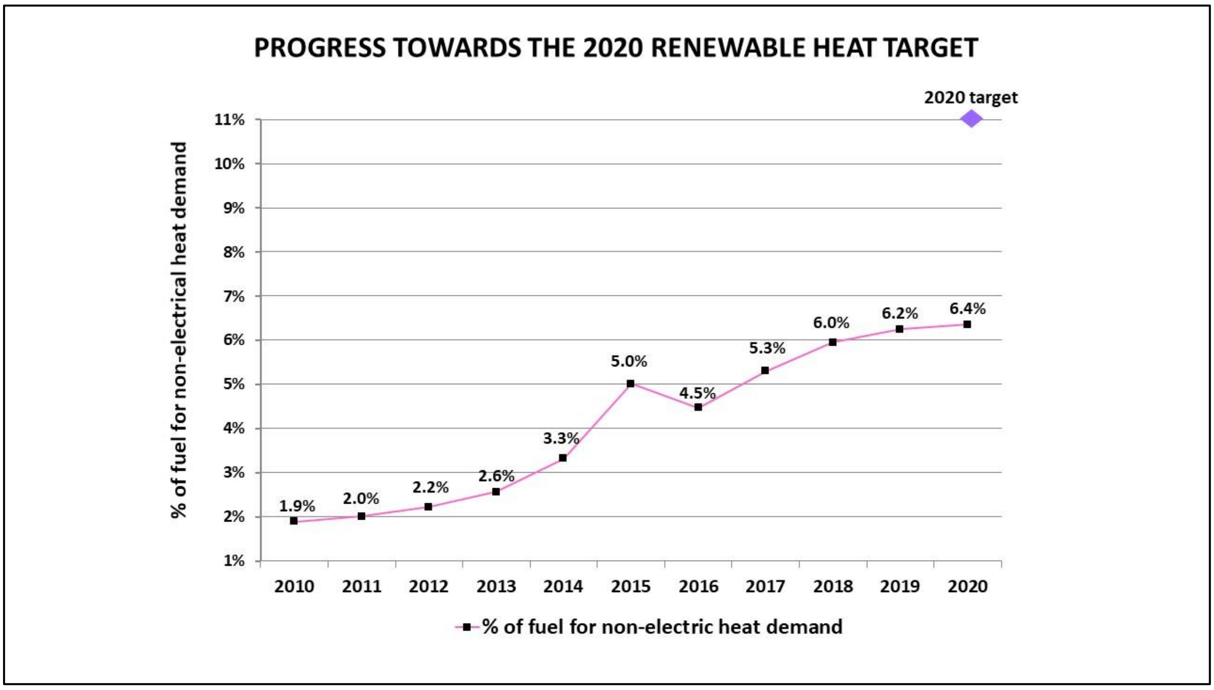


[1] Energy Statistics for Scotland - Q4 2022 - gov.scot (www.gov.scot)
[2] https://www.scottishrenewables.com/our-industry/statistics

Onshore wind is the largest supplier of renewable electricity in Scotland in 2023, with over 9,000 MW of installed capacity. Offshore wind has also been growing rapidly over recent years, with hydro coming third, followed by bioenergy and waste, solar PV and then wave/tidal.



The chart below[2] shows the quantity of heat produced each year from renewables, which shows again a steady increase but progress is currently well behind government targets.



Renewable energy – the opportunities?

Energy price hikes, insecurity in global energy markets and a desire to be more sustainable have resulted in many farmers looking at renewable opportunities and options to be more energy self-sufficient. Matching renewables to meet onsite demand can help to offset high energy costs and potentially generate additional income streams. Periods of high energy prices can also help to significantly reduce the payback period for renewable technologies.

The information in this guide highlights the main benefits, issues, resource requirements, financial considerations and any other considerations you need to take into account for each renewable energy technology. This guide will help you start to identify which technology could best fit with your farm and your objectives. Confirming whether or not a renewable technology will be economically and technically viable on your farm will require a detailed and thorough appraisal. You may find independent expert advice useful in this process; for complex projects this will be essential.

Renewable energy offers an excellent opportunity but only if it is carefully planned to fit with your business and your farm!

There are three important questions for you to consider:

1. Why should you invest in renewable energy?

Renewable energy can be an excellent choice for farmers seeking a diversification opportunity. The key benefits of renewable energy to your business are:

- Makes use of on-farm resources – from slurry to woodlands, and wind to rivers.
- Energy generated can be used to reduce electricity and heating bills on-farm.
- Power can be sold and exported to generate additional income.
- Reduction in greenhouse gas emissions.

2. Which renewable energy technologies are suitable for farms?

The renewable energy technologies which offer the best diversification opportunities for farms are:

- Wind energy
- Hydropower
- Anaerobic digestion/biogas
- Biomass
- Solar photovoltaic
- Heat pumps

3. What are your objectives for considering renewable energy?

Each renewable energy technology has different characteristics which will influence whether or not it is suitable for your farm. You need to carefully consider what your objectives are and what you want out of a renewable energy installation. The following factors are important to consider before deciding which renewable energy technology option(s) you wish to investigate:

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

More in-depth information and case studies can be found at:
www.farmingforabetterclimate.org

Farming for a Better Climate

Renewables after incentives

Previous government incentive schemes such as the Feed-in-Tariff (FIT) and Renewable Heat Incentive (RHI), used to be one of the main motivations and driving factors for small-medium farm scale renewable developments. With the removal of these schemes, it is even more important to fully investigate your options and various income opportunities to understand what developments would be economically viable.

It is important to assess your farm energy demand and discover what technology options would best suit your business. Firstly, improving energy efficiency and making best use of your existing systems and grid connection saves money and ensures you are investing in the right type and scale of technology.

Ideal renewable sites should be high yielding with low construction and connection costs. Viable farm scale projects will often help to meet as much onsite demand as possible to offset expensive energy bills. There are also potentially green marketing benefits by helping to offset fossil fuel use and lower overall carbon footprint.

Depending on the development, additional income options might include leasing land to developers e.g. for large-scale windfarms or ground mounted solar. Developers are typically looking for large sites with good access to the grid. Some developers are even beginning to look for suitable land to house large scale energy storage units. Power purchase agreements (PPA) or selling surplus electricity to the grid provide other income options.

Some government backed schemes and other funding opportunities are available and may help some developments. For example, the sixth Contract for Difference (CfD) round is expected to open for submission in early 2024 and could be expanded to include a wider array of renewable energy options. Subsequent rounds of CfD are likely to follow but may be aimed at specific technology types. The most recent round of contracts awarded included hydro, biomass, anaerobic digestion, onshore wind and photovoltaic options, but a lot of support has gone to larger scale schemes such as off-shore wind developments. Smart export guarantee (SEG) payments ensure that developers are paid something for the electricity they export to the grid, but these rates are often lower than the purchased price of electricity, so using the generated power to first offset bills is usually the best option.

There are some funding and support options available. Business Energy Scotland offer a SME Loan of up to £100,000 interest free, plus cashback grants for various renewable heat and energy efficiency measures. Home Energy Scotland can provide support for domestic properties, and banks and financial institutions often offer favourable rates for green projects.

Renewable costs are site specific and vary significantly depending on the type and scale of technology. Grid connection may be a limiting factor due to constraints across large parts of the network. Therefore, if you are exporting to the grid, it is imperative to speak to the network operator (DNO) at an early stage to understand connection options, timescales and costs. Connections below 50kW (on a three phase site) are generally more straightforward and lower cost.

More information on Ofgem environmental and social schemes including SEG: https://www.ofgem.gov.uk/environmental-and-social-schemes

More information on CfD: https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference

More information on Business Energy Scotland: https://businessenergyscotland.org/

More information on Home Energy Scotland: https://www.homeenergyscotland.org/

Wind energy

Wind turbines harness the power of the wind and use it to generate electricity. They are an effective renewable energy option on-farm in terms of electricity output. The best sites are those with an average wind speed of at least 6 m/s with an unobstructed exposure to the prevailing wind. Wind turbines are becoming larger and more efficient, providing opportunities to repower and scale up older existing sites.

Key benefits	– Attractive yields from well-located turbines with little input once operational. – Long-lasting and robust technology means wind turbines will last in excess of 20 years. – Require a small footprint of land which means that agricultural land loss is minimal.
Main issues	– High initial project risk – upfront costs can be considerable with no guarantee of gaining planning consent, i.e. submission of a planning application for a single medium to large scale wind turbine can cost upwards of £25,000. – Grid connection costs may be significant and are dependent on the distance to the nearest connection point, line capacity and any upgrades needed. These cost and delays in getting a suitable connection may result in a project not being economically viable and should be discussed with the network operator at an early stage. – Adverse impacts on the surrounding environment – careful assessment needs to be conducted to ensure any impacts are minimal and this would be addressed through the planning process.

	– Wind flow is not constant and varies in force and with the seasons. There will be periods when no electricity is produced at all and others where production exceeds local demand. – Wind energy can be a controversial option depending on the location and opinion of local communities.
Resource requirements	– Ideally, average wind speed greater than 6 metres per second. – A site with an unobstructed flow of wind e.g. no obstacles, such as trees and buildings, obstructing the prevailing winds.
Financial considerations	– Capital costs – costs for the turbine and associated infrastructure will vary depending on size, type and location of turbine (costs per kW are lower for larger turbines). Grid connection costs can also be significant. – Operational costs – typically costs about 2% to 3% of the capital cost. – Energy bill savings – electricity generated can be used on-farm and result in savings in electricity bills. – Income from exporting electricity – excess can be exported to the grid and receive payments through schemes such as Smart Export Guarantee (SEG) or negotiate a power purchase agreement. – Alternatively income can be obtained by supplying a local demand at a premium over the grid export value. – Support and Funding – the Community and Renewable Energy Scheme (CARES)[3] can offer a variety of support and funding to rural landowners

[3] https://localenergy.scot/funding/

	and community groups provided a degree of community ownership is included in the project. Business Energy Scotland[4] currently offer a SME Loan of up to £100,000 interest free for energy and carbon saving upgrades, plus additional support.
Other considerations	– Planning permission will be required. – Noise received at local residential properties must be considered and addressed in any planning proposal to protect amenity. – Ownership of land – who owns the land on either side of the proposed scheme? Who owns the land needed to access the site for construction etc? – Is the access for construction and maintenance suitable? – Environmental and landscape impacts – will development have an impact on sites protected for their natural heritage or landscape value, such as Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC) or Gardens and Designed Landscapes? – Archaeological and cultural heritage impacts – are there any designated sites such as Listed Buildings or Scheduled Ancient Monuments that could be affected? – Impact on airport/MOD radar and the interruption of microwave links – solutions are available but in some areas this will mean turbine development is not possible.

For further information visit: https://www.fas.scot/environment/climate-change/renewable-energy/

[4] https://businessenergyscotland.org/smeloan/

Hydropower

Hydropower schemes are well established in Scotland and harness the energy from flowing water to generate electricity, using a turbine or other device. The volume of flowing water and the height it falls determine how much electricity can be generated.

Types of technology	– **Storage based:** rainfall and surface drainage water are stored behind a man-made dam and then released to provide a constant, or demand-based, flow of water to the turbines to generate electricity. – **Run-of-river:** water is taken out of a stream, then fed downhill in a pipe and returned lower down river via a turbine.
Key benefits	– Annual energy output and seasonal variation is relatively predictable, varying with annual rainfall patterns. – Slow rate of change e.g. the output power varies more gradually following a rainfall event than output from a wind turbine does as wind speed changes. – Good correlation with demand i.e. output is maximum in winter. – Low environmental impact when installed on a suitable site. – Long-lasting and robust technology
Main issues	– Environmental impact – storage based systems can have a significant ecological impact due to the effect of the dammed water course on the surrounding environment. SEPA/SNH guidance requires the quantity of energy produced to be sufficient to justify any negative environmental effect to the watercourse

	and therefore sites with shallow falls may not be suitable. – Locating a suitable site – it can be difficult to find a site with all required characteristics, including both sufficient head and year-round water flow. – Grid connection costs may be significant and are dependent on the distance to the nearest connection point, line capacity and any upgrades needed. This cost may result in a project not being economically viable. Grid constraints including costs and time periods for connection need investigated with the network operator at an early opportunity.
Resource requirements	– Available head: this is the vertical distance the water would drop between the intake and the site of the turbine. The higher the head the greater the power produced for a given flow of water. – Flow rate: the volume of water that is available in the watercourse. This will depend upon the annual rainfall and nature of the catchment area.
Financial considerations	– Capital costs – these will vary depending on scale, site and type of system used. Grid connection costs can also be significant and should be investigated with the network operator. – Operational costs – estimated to be in the region of 2% of the capital cost per annum, less if a high proportion of the installation cost is infrastructure. – Energy bill savings – electricity generated can be used on-farm and result in savings in electricity bills. – Private wire export – in some cases added value can be obtained by supplying energy directly to an adjacent consumer at a rate higher than the export tariff.

	– Income from exporting electricity – excess can be exported to the grid through schemes such as Smart Export Guarantee (SEG) or negotiate a power purchase agreement with an electricity company.
Other considerations	– Planning permission will be required. – Ownership of land – who owns the land on either side of the proposed scheme? Who owns the land needed to access the site for construction etc? – Is the access for construction and maintenance suitable? – Operational input – low; regular oiling of the bearings and cleaning of the intake screen is required and this can be easily undertaken by local staff. – Environmental impacts – will development have an impact on sites protected for their natural heritage value, such as a Sites of Special Scientific Interest (SSSI) or Special Areas of Conservation (SAC)? – Interests of fisheries and leisure users of the watercourse also need to be considered. – Archaeological and cultural heritage impacts – are there any designated sites such as Listed Buildings or Scheduled Ancient Monuments that could be affected. – Water use licence – this will be required under The Water Environment (Controlled Activities) (Scotland) Regulations 2021 from SEPA.

For further information visit: https://www.fas.scot/environment/climate-change/renewable-energy/

Anaerobic Digestion (AD)

Anaerobic digestion (AD) is the process of biological decomposition of a feedstock in the absence of oxygen. This produces carbon dioxide and methane. The methane can be burned to generate electricity and heat or injected into the gas grid. Using wastes as the feedstock aids the sustainability and supports circular economy goals.

Types of technology	There are several different types of anaerobic digestion plant, some of the main options include: – **Thermophilic or mesophilic digestion** – most AD plants in the UK are mesophilic (digestion at 30 to 40°C) as they are generally considered to be more stable than thermophilic systems (digestion at 50 to 60°C). However, often as the digester matures after 1-2 years, an increasing number are moving towards thermophilic temperatures operating at 45 to 50°C. – **'Wet' or 'Dry' systems** – this depends on the feedstocks used. 'Wet' systems are typically up to 15% solids and can be pumped, 'dry' are usually 15 to 40% dry matter and feedstocks are stacked. In the UK most farm-based systems are wet systems. – **Single or multi-stage designs** – multi-stage systems offer the advantage of potentially higher biogas output as the main chemical stages are separated out and provides optimal conditions for different bacterial groups required. However, this adds greater complexity to the system and increases capital cost.
Key benefits	– Reduces emissions of methane from manures and agricultural residues (methane is a much more potent greenhouse gas than carbon dioxide). – May make use of waste products that have little or no other value.

- Reduces nuisance odours from farm wastes, as the digestion process takes place in a sealed tank.
- Provides water quality benefits from improved management of nitrogen and other nutrients present in manures and slurries.
- The digestate (material left over after digestion) can be used as a fertiliser replacement or soil improver, providing readily available nutrients. Digestate can be in a liquid or dried form.

Main issues

- Grid connection cost may be significant and is dependent on the distance to the nearest suitable connection point, line capacity and any upgrades needed. This cost may result in a project not being economically viable. If injecting straight to the gas grid then the equipment required to clean and upgrade the biogas can be costly.
- Small scale AD plants and projects are still developing and are not yet commonplace, (i.e. one that would suit a single average dairy farm) therefore these generally rely on additional crops or bought in wastes.
- For bought in feedstocks, security of feedstock supply and sensitivity to fluctuations in cost.
- Regulation and licensing can be onerous under the current rules for farm-scale plants if non-agricultural wastes are used.
- Quality assurance for digestate can be problematic if imported feedstocks are used.
- Accreditation schemes such as BSI PAS 110 and SEPA regulations exist to ensure compliance[5].

[5] https://www.farmingandwaterscotland.org/soil-nutrients/anaerobic-digestion-digestate/

Resource requirements	– Feedstock: any biodegradable plant or animal matter that is not woody e.g. animal manures and slurries, energy crops or food waste can be used. – The key consideration is the cost of the feedstock versus the biogas production per tonne (e.g. slurry may be a cheap feedstock but has low biogas production potential).
Financial considerations	– Capital costs vary depending on the scale of system. Additional capital costs such as grid connection and feedstock storage (for example silage clamps or slurry storage) can be significant. – Operational costs vary considerably and are dependent on the scale of the plant and feedstock used. Costs include: feedstock cost, transport and storage, labour and management, biological monitoring, maintenance and permits and licensing. – Energy bill savings – electricity and heat generated can be used on-farm and result in savings in electricity and heating bills. – Income from exporting electricity – excess can be exported to the grid through schemes such as Smart Export Guarantee (SEG) or negotiate a power purchase agreement with an electricity company. – Income from selling excess heat – if there is a third party heat demand in the vicinity of the plant then direct sales may be possible at a premium over the export tariff.
Other considerations	– Planning permission will usually be required. – Operational input – a small system running on silage and slurry will require significantly less input on a day-to-day basis than a larger plant taking in catering waste.

- Space – is there sufficient space for the digester tank, feedstock storage, digestate storage and ancillary equipment?
- Location – if planning to use the heat, the plant will need to be located near heat demand.
- Access roads need to be suitable for feedstock delivery vehicles and they may need to meet the requirements of various licences and regulations.
- Regulations and licensing – this will vary depending on the nature and source of the feedstock and use of the digestate e.g. EU Animal By-products Regulations, BSI PAS 110, PPC Regulations, Waste Management License, Duty of Care and Waste Carrier License.

For further information visit: https://www.fas.scot/environment/climate-change/renewable-energy/

Biomass

Biomass boilers use either woodfuel or straw to generate heat, which can be used for almost any heating need on the farm.

Types of technology	There are several types of biomass boiler: – Woodchip boilers. – Pellet boilers. – Log boilers. – Straw boilers. – Multi-fuel (e.g. straw and logs, log and pellet).
Key benefits	– Generally no external barriers to installation e.g. if required, obtaining planning permission is usually relatively straight forward. – Tried, tested and efficient technology. – No specific resources are required on-farm, only a heat demand.
Main issues	– Fuel costs need to be factored in, and have seen increases over recent years. Viability without incentives needs careful consideration. – Poor design and installation – can lead to systems which do not function efficiently. – Poor design of the fuel store – can lead to inefficient and expensive deliveries. – Mismatch of boiler fuel requirements to the type and quality fuel available locally. – Poor fuel quality – issues such as high moisture content, contaminants or out of specification particle size will lead to a variety of problems.
Resource requirements	– Producing your own fuel can aid the viability of biomass projects.

	– Logs or woodchip can be produced on-farm; pellets cannot. – Wood fuel production on farm can stimulate improved woodland management and may result in increased value of the woodland in the long term. It usually results in lower fuel costs and increased security of supply.
Financial considerations	– Capital costs vary depending on the size of the system, type of fuel, level of sophistication, whether it is a retro fit, containerised system or a new build. In general, basic straw bale burners and log boilers are the cheapest of the biomass boilers, followed by more sophisticated gasification log boilers, pellet then woodchip boilers. – Operational costs – fuel costs depend on the fuel selected, whether produced on-farm or bought in, delivery distances and production methods employed. Pellets are the most expensive wood fuel. Maintenance costs depend in part on the type and size of the system, as well as how hard the boiler is working. Average servicing costs are between £500 and £1,000 per year. – Energy bill savings need careful consideration and calculation compared to heating oil, gas or electric options. – Income from selling excess heat – if there is a third party heat demand in the vicinity. – Support and Funding – Business Energy Scotland[6] currently offer a SME Loan of up to £100,000 interest free for energy and carbon saving upgrades, plus additional support. Cashback grants of 75% of

[6] https://businessenergyscotland.org/smeloan/

eligible costs up to a maximum of £10,000 can also be claimed for a range of renewable heat measures (including biomass boilers).

Other considerations

- Planning permission – not always required, but is usually straight forward to obtain. May be more complex if listed buildings are involved.
- Space – biomass boilers require far more space than an equivalent oil boiler and often need extra space around them for access and servicing. Size of the fuel store will depend on the fuel and the desired frequency of deliveries.
- Access and fuel delivery – fuel store should be designed based on delivery vehicles which are available in the area and which can access the site.
- Manual loading or automatic feed – log boilers are manually loaded; pellet boilers and woodchip boilers are automatically fed.
- Operational input – pellet boilers tend to require less day-to-day attention than a woodchip system. Boilers vary in their level of sophistication, for example some have features for cleaning the boiler tubes, flue and grate, whereas other boilers will need this to be done manually.

For further information visit: https://www.fas.scot/environment/climate-change/renewable-energy/

Heat pumps

Despite being classed as renewable, heat pumps use electricity, but far less than you would for direct electric heating. Combining with other farm renewables to provide the electricity can be beneficial. Heat pumps can help to meet both heating and cooling demands on site.

Types of technology	– Heat pumps themselves are all basically the same in how they operate - a fridge in reverse. However, what differs is the source they extract heat from. They require a source of heat, to take low grade warmth and concentrate it to a higher temperature that can be used. Common sources of low grade heat are: – Ground source – Water source – Air source – All heat pumps use electricity to run, but at most times will give more heat out than electricity used. The ratio of electricity used to heat out is known as the Coefficient of Performance (COP). However, this varies depending on the temperature of the source of heat and the temperature required for the heating water. In the summer (when most users don't need much heat) an air source COP could be as high as 6, but in the winter as low as 1.5. Therefore, it is best to consider the performance throughout the year, this is known as the Seasonal Performance Factor (SPF). – Air source heat pumps, have the simplest and cheapest installation very similar to an air conditioning unit, but have the lowest performance (SPF) which can be as low as 2-2.5.

- Ground source heat pumps take advantage of the ground not changing temperature very much throughout the year, therefore providing good performance in the winter, when heat is needed most. SPF of 4 is common.
- Water source heat pumps use a body of ground water such as a lake, river, well, borehole and so on. Ground water temperatures in the UK are more constant than the air but not quite as constant as the ground. However, as water transfers heat best, usually water source heat pumps have the best performance of all. Water source heat pumps have a lower installation cost than ground source as there are no trenching costs.
- More recently, hybrid systems have been developed which use the ground in winter and the air in summer, giving the best all round performance.
- Traditionally heat pumps have been used on the smaller single premises domestic scale, however it is quite possible to develop systems of several hundred kilowatts, especially on farms where space for ground loops is less of an issue. Also, it is possible to supply district heating systems via heat pumps, or indeed for several properties to share a ground loop.

Key benefits

- Fuel bill savings – especially if using a cheap source of electricity such as onsite renewables.
- Generally no external barriers to installation e.g. if required obtaining planning permission is usually relatively straight forward.
- Tried, tested and efficient technology.
- No specific resources are required on-farm, only a heat demand.

Main issues	– Poor design around existing heat emitters – systems which require high water temperatures can lead to systems which do not function efficiently.
Resource requirements	– For farms with an existing cheap or free electricity supply e.g. wind turbine, the financials can be good.
Financial considerations	– Capital costs – vary depending on the size of the system, heat source, level of sophistication and whether it is a retro fit. – Operational costs – for users buying electricity. – Energy bill savings – depending on the current fuel it is replacing and current energy prices. – Income from selling excess heat – if there is a third party heat demand in the vicinity.
Other considerations	– Planning permission – unlikely to be required. May be more complex if Listed Buildings are involved. – Space – the heat pumps themselves are only slightly larger than the equivalent fossil fuel boiler. – Can be beneficial on farms that have both a heating and cooling demand, such as a cold store and grain dryer. However it is unlikely to meet all of the heat and cooling demand for these processes, but will help to offset a proportion of existing fuel use.

For further information visit: https://www.fas.scot/environment/climate-change/renewable-energy/

Solar Photovoltaic (PV)

Solar power refers to energy derived from the sun in terms of either direct heat or daylight. Solar photovoltaic (PV) systems convert sunlight into electricity for use on site or for export to the grid. Often the simplest option and easiest to get consent. Solar thermal units can also help to meet heat demands on farm but are not discussed further in this guide.

Types of technology	There are several PV systems that can be used: – Solar panels retrofitted onto building roofs. – Solar tiles and slates integrated into roofs (usually new build). – Ground mounted solar panels.
Key benefits	– Easy to install and can be retrofitted to existing infrastructures. – Require minimal maintenance. – Very few external barriers to installation for small scale systems. – Short lead time from feasibility to installation.
Main issues	– Intermittent electricity generation – entirely dependent on seasons, time of day and geographic location. Times of electricity generation may not match the times of your electricity demand.
Resource requirements	– Roof-mounted installations require areas of unshaded, structurally sound, south-facing roof space. – Ground mounted solar PV installations require a large, unshaded area of land.
Financial considerations	– Capital costs – vary depending on the scale of system and type of panels.

	– Operational costs – components of the system are simple and require little maintenance – an annual service is recommended by suppliers. – Energy bill savings – electricity generated can be used on-farm and result in savings in electricity bills. – Income from exporting electricity - excess can be exported to the grid through schemes such as Smart Export Guarantee (SEG) or negotiate a power purchase agreement with an electricity company.
Other considerations	– Planning permission – will be required for some types of installation, but is usually not required for smaller roof-mounted installations which fall under Permitted Development rights. However, exceptions exist therefore should be checked with the local planning authority.

For further information visit: https://www.fas.scot/environment/climate-change/renewable-energy/

Energy storage, demand management and electric vehicles

The variable nature of Scottish weather results in a wide variation in the quantity of energy available from hour to hour from the many renewable generators now operating in the country. This makes it difficult to maximise the carbon benefits gained by offsetting the use of fossil fuels and the financial benefit for scheme owners. Technology with the ability to store energy for use when a demand exists is developing rapidly and the commercial mechanisms to allow operators of storage facilities to generate revenue streams from their operation are evolving. In many current farm scale renewable installations, such as wind turbines, solar PV panels and run-of-river hydro schemes, energy is produced when the natural resource is available and if no on-site demand exists at that time it is exported to the local grid.

Before now, storage has rarely been viable at the farm scale, but high electricity prices and advancements in technology are changing that. They can be viable for providing power to off-grid locations, storing your own renewables if you have a poor export contract, or even buying and storing cheaper night-rate electricity for use in daytime.

1. Battery storage – for on-site use

The addition of energy storage such as that provided by batteries can provide a buffer so that on-site use can be varied from the time of generation. The existing advantage of this for on-site use is that more expensive imported energy can be offset by renewable generation. As battery prices fall, coupled with high electricity prices rises, this could become a viable option for many more generators in the near future. Different type of batteries include:

- **Lead-acid** based is lowest capex, but generally higher lifetime costs and they work in low temperatures.
- **Lithium** based is higher capex but lowest lifetime costs, they don't work as well in low temperatures and there can be long lead-times.
- **Flow batteries**, are a new technology, but could soon replace lithium for large scale storage options, but are not for space limited situations.

- **Thermal storage** either through heating water and storing in an insulated tank for later use, or heat batteries employing phase changing materials will provide a more efficient heat storage medium in a smaller space. Financial consideration of the energy source being substituted is essential.

2. Battery storage – for energy export

As the electricity grid becomes more sophisticated, “price signals” will be available in real time which will allow the energy market to become much more dynamic and pricing based on demand will be possible. Rather than agreeing a fixed rate per unit of energy fed to the grid or even separate fixed rates based on season or time of day, it will be possible to obtain variable rates depending on real-time demand. When demand is high even small generators may be able to sell their energy at a premium price. Similarly where grid capacity restrictions apply, real time signals could be used to curtail the export from a generator allowing them to be connected without the need for expensive grid upgrades. Work is currently ongoing to enable these new commercial arrangements to be introduced for generators of all scales. On site battery storage will provide additional flexibility to take advantage of these new commercial arrangements.

Independent storage facilities on a larger scale could provide useful benefits to electricity network operators, allowing them to balance generation from renewables with fluctuating demand. Policy and regulatory barriers to this type of installation are currently being reviewed to ensure that their development is not unduly hindered.

“Grid Balancing” services to the National Grid are developing but they are currently fairly difficult and income potential is limited. However, the DNO’s are due to take control of some of these services and control them locally, which could open up a wider range of services to smaller storage systems.

3. Demand management

The grid management techniques described above can also be used to control on-site demands in order to take advantage of lower energy pricing when demand on the network is low. For example, building “cold” in a potato store when lower priced electricity is available avoids the need to purchase more expensive energy when demand on the grid is high.

Another advantage of this kind of facility and smart grid technology is the reduction in the need to upgrade electricity networks based on the maximum possible load that could occur from all of the generation capacity (and demands) connected to it. Instead generators can be curtailed or local demands turned up or down to prevent overload of the network based on real time data.

4. Electric Vehicles (EVs)

The Scottish Government has set a target to phase out new petrol and diesel cars and vans by 2030 to help create a healthier, cleaner, and greener Scotland. With reducing battery costs, improvements in battery capacity (and hence vehicle range) and a rise in rapid charging points, a large increase in electric vehicle use within the coming decade is expected. Where charging can be done using on-site renewables, electric light vans and cars are even more worthy of consideration.

The relatively large loads that large numbers of EVs could impose on parts of the electricity network at certain times of the day could be problematic and therefore a level of network management may become necessary. Opportunities may develop with the advent of smart grid management techniques whereby EV owners could join an EV group, plug in to their charging point and enter the time by which they require the vehicle to be charged. Using computer software the group manager could then schedule the charging of all vehicles to maximise the use of local renewable energy and avoid overloading the grid, whilst ensure that all vehicles were available when required by their owners. Electric vehicles also have the potential to aid energy storage, by effectively being an on-site mobile battery.

5. Hydrogen production

Hydrogen is versatile and can provide multiple uses, including as a vehicle fuel, producing electricity in a fuel cell, green fertiliser production or for energy storage.

Renewable “green” hydrogen is produced by electrolysis using exclusively renewable electricity. It is expected to play a key role in achieving net zero emissions in Scotland. The fuel cell market is currently smaller than the electric battery market. It is nevertheless projected to increase and with it the need for hydrogen refuelling stations. These stations can be designed to take advantage of off-peak renewable generation by utilising larger electrolysers and storage facilities for hydrogen. The Scottish government has committed over £100 million in investments for this technology going forward to help improve hydrogen infrastructure. Over the next 20 years Scotland has plans to increase its hydrogen production up to 25GW by 2045.

Units

Joule (J)	The basic unit of energy (or work) is the joule.
Watt (W)	Power is measured in Watts and 1 Watt (W) = 1 joule per second (J/s).
Kilowatt (kW)	A measure of power equal to 1,000 W. Energy installations are often rated by their maximum power output in kW. Heat installations are measured as kW thermal (kWth). Therefore an electrical generator rated at 100 kW and running at its full capacity will produce 100,000 joules of energy per second (J/s) or 100,000 x 60 x 60 = 360,000,000 joules per hour (J/h). For convenience a more manageable unit such as the kWh is more commonly used to measure energy.1 kWh = 3,600,000 joules.
Megawatt (MW)	A unit of power equal to one million watts.
Kilowatt hour (kWh)	A measure of total energy produced, one kWh being also known as a “unit” of electricity e.g. a boiler of 500kW rating, running at full power for one hour, will produce 500kWh of heat.
Megawatt hour (MWh)	1 MWh = 1000 kWh
Gigawatt hour (GWh)	1 GWh = 1000 MWh

Interesting fact: A typical bowl of porridge will provide 1153 kJ of energy or 0.32 kWh.

Useful Terms

Anaerobic digestion	A biological process where bacteria breakdown organic matter under oxygen-free conditions to produce a biogas containing methane.
Biogas	A combustible gas produced by the biological breakdown of organic matter in anaerobic conditions (for example, methane). Used to generate heat and electricity, or can be cleaned and upgraded into gas for the grid.
Biomass	Any biological material derived from living, or recently living organisms. Includes everything from wood waste to other plant and animal matter.
Combined heat and power	The sequential production of electricity and heat from the same fuel source.
Contract for Difference (CfD)	A private law contract between a low carbon electricity generator and the Low Carbon Contracts Company (LCCC).
Controlled Activity Regulations	A framework for the development of risk-based and proportionate measures to control impacts on the water environment and safeguard sustainable water use for now and future generations.
Digestate	A nutrient-rich substance produced by anaerobic digestion that can be used as a fertiliser. It consists of left-over indigestible material and dead micro-organisms. Often separated into solid and liquid portions prior to spreading on land.
Digester	The tank in which anaerobic digestion takes place. Many AD plants will have both a primary and a secondary digester to maximise gas production.
Distribution Network Operator (DNO)	Licensed operators of the distribution grid network, including cables, transformers and towers that bring electricity from the national transmission network to businesses and homes. In Scotland these are Scottish and Southern Electricity Networks and SP Energy Networks.
Environmental constraints	Environmental constraints data is made up of the locations and classifications of areas deemed to be of natural importance. These areas have restrictions that may limit the extent and type of development that can take place and knowing the type and location of these designated areas is important during the planning process.

Environmental impact assessment	A study of the environmental effects of a proposed project.
Feedstock	Generic term for any biomass resource used for conversion to energy or biofuel.
Feed-in Tariff	An incentive scheme designed to promote the generation of renewable electricity production via long-term index-linked payments. Launched in April 2010 and closed in April 2019. Payment rates varied depending on type and size of technology employed and are subject to periodic review.
Hydropower	Using running water to generate electricity, whether it's a small stream or a larger river.
Impoundment scheme	An impoundment is any dam, weir or other structure that can raise the water level of a water body above its natural level.
Microgeneration Certification Scheme (MCS)	An industry-funded assurance scheme to ensure the quality of renewable technology installations, companies and products.
Methane	The odourless, flammable gas produced during anaerobic digestion. Can be captured and used to generate energy.
Pellets	Wood pellets are manufactured on an industrial scale from a variety of products such as saw dust, virgin timber, and saw mill co-products.
Permitted Development	A type of development that can be carried out without planning permission.
Renewable Heat Incentive	Renewable Heat Incentive was a Government scheme to encourage the uptake of renewable heat technologies. It made a payment for every unit of heat produced. Payment rates varied depending on type and size of technology employed and were subject to periodic review. It was the first financial support scheme for renewable heat in the world and opened in November 2011 and closed the domestic RHI closed in March 2022 and non-domestic RHI closed in March 2021.
Return on investment	Return on investment analysis compares the magnitude and timing of investment gains directly with the magnitude and timing of investment costs.

Renewables Obligation	Formerly the main support scheme for renewable electricity projects in the UK. It places an obligation on UK electricity suppliers to source an increasing proportion of their electricity from renewable sources. Suppliers meet their obligations by presenting sufficient Renewables Obligation Certificates. Where suppliers do not have sufficient ROCs, they must pay an equivalent amount into a fund, the proceeds of which are paid back on a pro-rated basis to those suppliers that have presented ROCs. The scheme closed to new applications in March 2017.
Renewables Obligation Certificate	A green certificate issued to an accredited generator for eligible renewable electricity and supplied to customers within the UK. One ROC is issued for each megawatt hour (MWh) of eligible renewable output generated, although some technologies get more, some less. The scheme closed to new generators in March 2017.
Run-of-river scheme	Run of river hydro projects use the natural downward flow of rivers and micro turbine generators to capture the kinetic energy carried by water.
Smart Export Guarantee (SEG)	SEG launched on 1 January 2020 and is a government-backed initiative, which replaced the export part of the FIT. The SEG requires some electricity suppliers, known as SEG Licensees, to pay small-scale generators, known as SEG Generators, for low-carbon electricity which they export back to the National Grid, providing certain criteria are met.
Solar energy	Energy provided directly by the sun's rays.
Solar thermal	The use of heat from the sun to provide space heating or hot water.
Solar photovoltaic (PV)	The conversion of sunlight to electricity
Woodchip	Wood chips in the UK are usually produced from poor quality virgin timber, with a chipper designed to produce woodfuel quality chip. Strict quality standards exist for commercial producers.
Woodfuel	Wood used as a fuel (generally includes logs, woodchip and pellets)
Yield	The amount of energy produced by a renewable energy technology.

Useful Contacts

Business Energy Scotland	https://businessenergyscotland.org/
Carbon Trust	http://www.carbontrust.com/
Department for Business, Energy & Industrial Strategy (BEIS)	https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy
Energy Saving Trust	http://www.energysavingtrust.org.uk/
Farming for a Better Climate	www.farmingforabetterclimate.org
Scotland's Farm Advisory Service	https://www.fas.scot/
Home Energy Scotland	https://www.homeenergyscotland.org/
Local Energy Scotland CARES	https://localenergy.scot/funding/
NatureScot	https://www.nature.scot/
Ofgem	http://www.ofgem.gov.uk/
Renewable Energy Association (REA)	http://www.r-e-a.net/
RenewableUK	http://www.renewableuk.com/
Scottish Government	https://www.gov.scot/energy/
Scottish and Southern Electricity Networks	https://www.ssen.co.uk/
Scottish Renewables	http://www.scottishrenewables.com/
SEPA	https://www.sepa.org.uk/
SP Energy Networks	https://www.spenergynetworks.co.uk/
The Microgeneration Certification Scheme	http://www.microgenerationcertification.org/