Fellfoot Forward:

Farm Solar Report – Introductory guidance

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Prepared on behalf of Cumbria Action for Sustainability

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1. Introduction

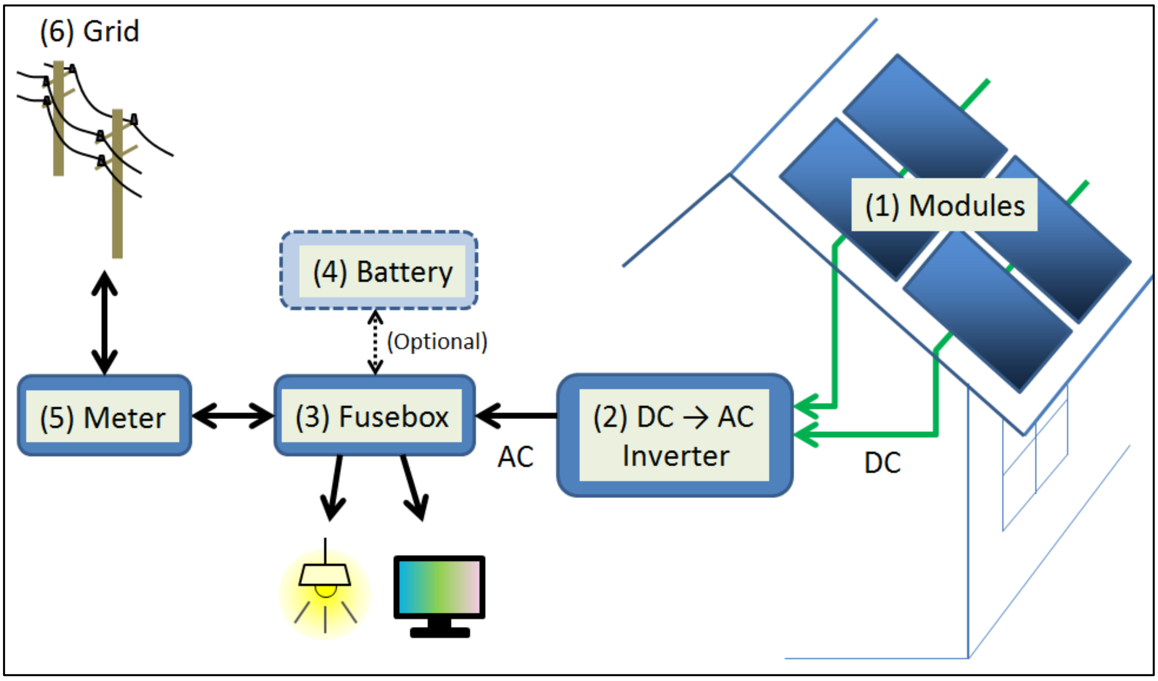
This report provides the results from assessments carried out on how solar energy could potentially benefit five farms in the Fellfoot Forward area. The work was carried out as part of the Farming Futures project.

The aim was to provide advice to farmers to explore whether solar energy could help to cut their costs and carbon footprint.

The report is divided into a main report that provides general explanations and information on issues to think about when considering a solar system and individual annexes looking at the results for each farm visited.

2. Photovoltaic Solar Energy Systems Fundamentals

This report looks primarily at solar photovoltaic (PV) installations and role they can play in supporting farmers to reduce carbon emissions and electricity bills. A solar PV installation is made up of a number of key components, as shown in the diagram below.



The key components are:

1. **Solar PV modules or solar panels**. An array of modules will normally sit on a roof or independent mounting structure. Each module will generate direct current (d.c.) electricity when exposed to light. The amount of electricity generated depends on the number of modules and the strength of the sunlight hitting the modules at the time. Modules are best positioned so that they face the sun as much as possible. They need to be tilted (partly to help keep them clean) and orientated towards the south, east or west.

2. The d.c. electricity generated by the modules is fed from the modules into an **inverter** which converts the electricity in alternating current (a.c.) electricity with the same voltage and frequency as the electricity supply network (the grid).
3. There will also be a **fusebox** / protection system. From here electricity can be supplied to loads in the house or farm.
4. There may be a **battery** which can store electricity for a few days or hours until needed. Batteries can be used with systems connected to the electricity network as shown or with stand-alone systems disconnected from the electricity network.
5. If the system is connected to the electricity network there will generally be a **meter** installed to measure the flow of electricity coming from or going to the network.
6. The local electricity supply network or **grid**.

A typical PV module today is around 1.755m long and 1.04m wide, they can be positioned either landscape mode or portrait mode. Output power of a module varies according to the model chosen but a good quality module made using crystalline silicon will have a rated maximum output power of 360-420 watts peak (Wp). An array of 10 modules will have an output power of 3.6 to 4.2 kilowatts peak (kWp) and require an area of around 18m^2.

The farm buildings we have considered for mounting PV systems were mainly shed type constructions with a roof slope of 15^o. A shed roof would typically provide space for 10 to 30 kWp of PV, depending on the shed size and the number and position of rooflights. Larger systems may require using multiple roofs.

3. Energy outputs

The energy output obtained from a PV system will depend on the size of system, the time of year, the position of the array and the weather on the day. The optimal position (slope and orientation) depends on where you are in the world. In northern England a slope of 39^o with an orientation due south are optimal. However, orientations from south-west to south-east and slopes ranging from 15^o to 60^o can have outputs within 94% of optimal. A south-east/west facing orientation with a slope of 15^o will still be above 90% of optimal. In fact, the optimal slope becomes shallower as you move away from south, for a shed roof facing just south of E or W a slope of 15^o is actually optimal, see table below.

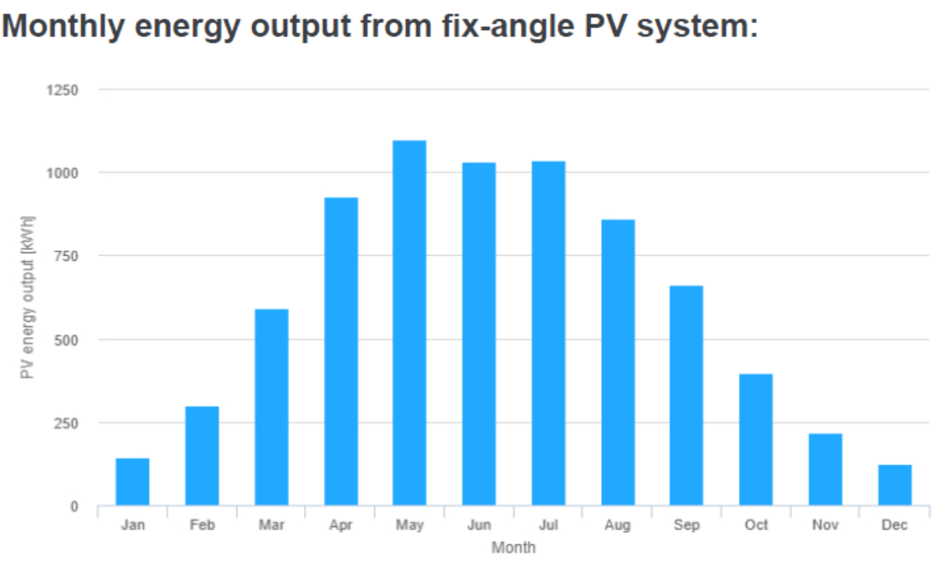
In the Fellside area each kWp of installed solar power on a south facing shed roof can be expected to generate an average of 793 kWh a year. The table below compares the annual energy outputs for a <u>10kWp</u> PV system with different roof positions in the Fellside area.

Table 1: Annual energy outputs for a 10kWP PV system in the Fellside area.

For a 10kWp roof mounted PV system in the Fellfoot area	Slope	Orientation (degrees off south)	kWh/yr	% of optimal
Optimal position	39	0	8436	100%
South facing shed roof	15	0	7928	94%
SE or SW facing shed roof	15	45	7659	91%
Optimal slope for SE or SW facing roof	36	45	7923	94%
For a shed roof facing just south of E or W a slope of 15° is actually optimal.	15	80	7182	85%

The average yearly PV energy production has been calculated using the PVGIS tool. This will calculate annual and monthly energy outputs for PV systems anywhere in the world, with any orientation and slope. It is publicly available for free at this link: https://re.jrc.ec.europa.eu/pvg_tools/en/.

The graph below, created using PVGIS, shows how energy production from a 10kWp PV system (slope 15°, orientation (also called azimuth) due south) varies over the year from a low of 125 kWh per month in December and January to a high of over 1000 kWh per month from May to July.



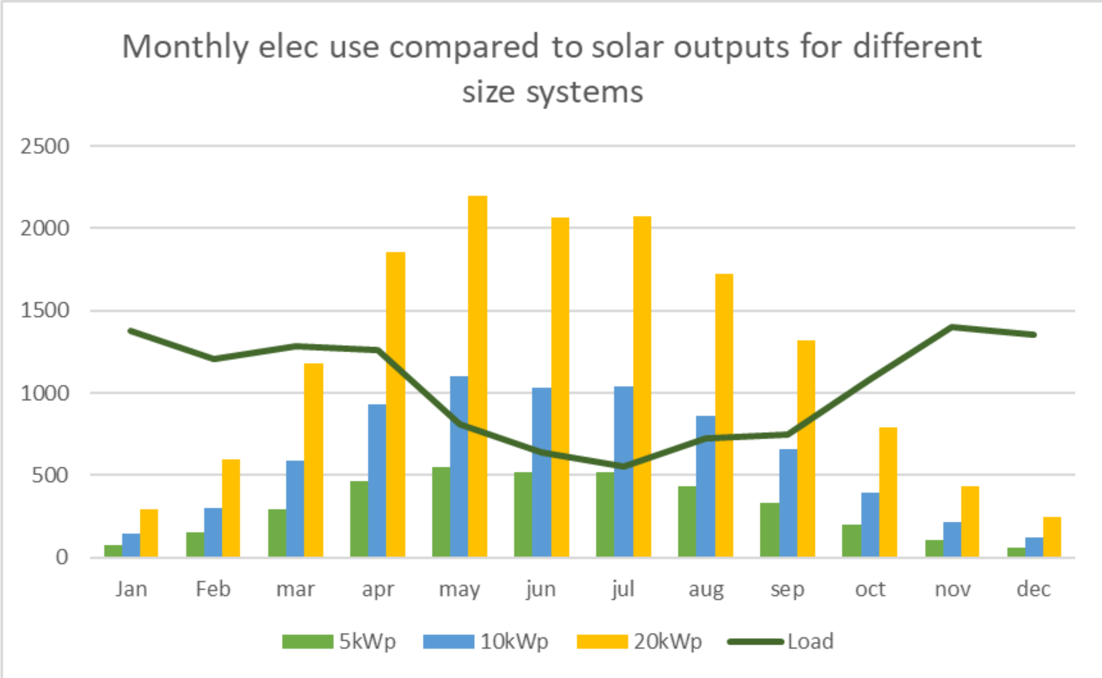
4. Matching energy outputs and loads, batteries and time shifting loads

The value of the energy produced by a solar system strongly depends on what proportion of the energy is used directly, displacing electricity bought from the grid (which may be charged at day rates and night rates) and the proportion of the electricity that is exported, which is usually worth much less than purchased electricity. The rates charged for electricity vary between different suppliers, tariffs and contract dates but have generally gone up significantly in the last year. To calculate the costs and benefits for this report a price range of 35-55p/kWh was used. This is much higher than the 5.6p/kWh typically obtained for surplus electricity exported to the grid under the Smart Energy Guarantee scheme. This means it is important to size a solar system correctly so that most of the energy generated is used on the farm with a minimal proportion exported to the grid.

It is also sensible to consider whether or not loads are likely to change in the near future, for example if electric vehicles are expected to be used.

Battery systems are available that can store surplus electricity for a few hours or days for use later. This can help maximize the proportion of electricity that is used to displace electricity purchased from the grid. However, batteries are expensive and will need replacing every 10 years or so. Having a battery bank big enough to store surplus energy from the summer months for use later in the year is not practical. Deciding whether or not a battery is needed and what size battery to install will require consideration of the size and pattern of daily and seasonal loads. If loads are generally smaller than generation and are fairly steady across the day a battery may not be worthwhile. If loads tend to be erratic or concentrated at morning and evening milking time a battery may offer some benefit.

To assist in considering what size of PV system would be best and whether or not a battery would be useful the monthly energy outputs from different sizes of PV systems were compared to the monthly electricity load for each farm considered. The example graph below compares monthly energy use (load) to potential PV energy generation for 3 different sizes of PV systems for each month of the year. At the farm used for this example the load dips substantially in the summer months as there is no dairy herd. This reduces the size of solar system it would be worthwhile installing.



In this example the smallest system considered (5kWp) is the green bars. Generation is consistently below electricity consumption so for most of the year nearly all of the solar energy could probably be used on the farm displacing purchased electricity. If the loads are erratic there will probably be times in the summer when more electricity is being generated than is being used. The choice is then to allow surplus electricity to spill out onto the grid or store it in a battery system for use later in the day. As generation is well below load for most of the year this may only occur occasionally in the summer months and the financial benefit may not outweigh the cost of a battery.

The mid-size system (10kWp) is the blue bars. Generation is around the level of consumption in April and September, somewhat above consumption the summer and below in the winter months. If the time of day of loads matches the solar generation times well then over the year the majority of the solar energy generated should be used on the farm, although surplus energy will be exported in the summer months. Installing a battery may be worthwhile as it would allow solar energy to be stored for use at night or when the daytime load exceeds the generation at the time. However, the financial return would probably be better if a slightly smaller solar system was installed than 10kWp.

The large-size system (20 kWp) is the yellow bars. Generation is well over the level of daytime consumption from April to September, and the system will be oversized unless the loads increase. Significant amounts of electricity are likely to be exported in the summer. This means the financial return will be very dependent on the rate that can be achieved for exported electricity. Currently the rates on offer are fairly low, typically 5.6p per kWh, although better rates are available in some circumstances.

To decide whether or not a battery system would be beneficial and what size of battery to install you need to consider how well the load times matches the solar generation times. To do this you can read the meters every couple of hours in the daytime for a few days to check how much electricity consumption occurs over the middle of the day and how much late or early in the day or overnight. You may want to repeat this at different times of year if the load pattern is likely to change with the season. If a significant proportion of electricity consumption is early or late in the day adding a battery to the solar system may be worthwhile but does add significantly to the cost.

If it is possible to shift any loads to the middle of the day when solar generation is likely to be highest that will be beneficial.

5. Exporting electricity and the Smart Export Guarantee

If PV energy production cannot be used directly any surplus automatically spills out onto the local electricity supply network. Owners can receive payments for this exported electricity under the Smart Export Guarantee. This is offered by various energy suppliers but the tariffs available vary from 1p/kWh to 34p/kWh. Rates of 5.6p/kWh are fairly standard but better rates may be achievable. The Money Saving Expert website offers a good explanation, see https://www.moneysavingexpert.com/utilities/free-solar-panels/.

6. Electricity Supply Network Constraints

The electricity supply available at a farm will generally impose some limit to the amount of generation that can be connected to the supply. The electricity network, particularly in these very rural areas, has grown up ad hoc and there seems to be little correlation now between the size of the loads at a farm and the size of the supply to the farm.

Some micro-generators such as small-scale solar systems can be connected to the electricity network under the G98 recommendations without the need for pre-approval from ENW. Larger systems need to be reviewed by ENW to see if the local electricity supply network could cope with the additional generation capacity.

The Small-Scale Embedded Generation (SSEG) limit (the G98 limits) are 3.68 kW for single phase and 11.04 kW for 3 phase supply. For systems below these limits the installer just informs ENW after the system is installed.

Bigger generation systems are connected under G99 engineering recommendation. For these, before you connect, you need permission from the local Distribution Network Operator (DNO) / Distribution System Operator (DSO). In our area this is Electricity North West (ENW).

ENW do not charge for applications under G98 or G99 if the systems are below 1MW is size, which is much bigger than the systems we are considering. However, an installer may make a charge of £200-£300 to submit an application on your behalf. This is likely to be non-refundable if the application is rejected.

The supply to each farm was reviewed and discussed with Electricity North West to establish where possible the approximate supply and generation capacity available, the possibilities for upgrading the supply and the order of magnitude of the costs involved.

The size of the supply available is also likely to limit the size and number of any electric vehicle (EV) chargers installed. Most farms visited did not have a 3-phase supply and hence would not be able to install rapid chargers. The capacity currently available at most of the farms would probably allow for 1 or 2 standard 3kW, or possibly 7kW chargers, but if more charging capacity was needed then the supply would usually need to be upgraded.

At the 5 farms visited the generation capacity that could be connected to the network without any upgrading ranged from 3.68kWp at one farm to possibly 20kWp at a couple of the other farms. Potential upgrades identified included:

- installing a new supply line from an existing transformer to connect any new generation to, or to connect EV chargers to. This was estimated to cost around £4000 for the site reviewed.
- replacing a 25kVA pole mounted transformer with a 50kVA or 100kVA transformer. A transformer change is typically in the region of £30k - £45k, subject to a detailed network assessment. However, if there is more than one supply provided from the transformer the cost should be reduced to a proportion of the total cost. For the location reviewed the transformer also suppled a phone mast, so cost apportionment could reduce the cost to the farm to £10000-15000.

In some cases, the situation was more complex and ENW advised they would need further study and investigations to determine what was possible and the costs involved.

While any supply can be upgraded the cost of major upgrades is likely to be prohibitive for the relatively small generation capacities considered for this project which ranged from below 5kWp to 60kWp and cost between £5500 and £72000. The more expensive upgrades could double the cost of the solar system and would probably not be cost effective unless there were other reasons to upgrade the supply.

The rules on costs for generation connections are changing on 1st April 2023. After this date all generation connections will pay for reinforcement work done (apportioned if applicable) at the same voltage as the connection. Any reinforcement work required at higher voltage levels will be covered by the DNO’s. This charge is unlikely to make a difference to small generation projects such as those considered here.

It is possible to contact the Customer Engagement team at ENW connections department who offer surgery sessions in which they can look at the network to a site and provide a steer of what is in the art of the possible. They can also assist with submitting applications.

Contact person: Simon Taylor
Customer Engagement team
Electricity North West Ltd connections department
Simon.Taylor@enwl.co.uk

7. Export Limitation

In some cases, it is possible to install a bigger generation system or load than initial investigations suggest if a customer limitation scheme is installed. These use devices that limit either the demand that can be supplied at any one time or the generation that can be exported at any moment. This link is to a case study from an inverter manufacturer that offers an export-limitation product. https://www.sma-uk.com/solar-systems/export-limitation.html

These schemes can be useful in the right circumstances but care does have to be taken to ensure that they do not regularly constrain the output from a system and reduce its cost effectiveness.

8. System Costs

The costs of solar systems have been dropping for decades. However, supply issues over the last year and disruptions due to Covid and the war in Ukraine have led to some recent price rises. The prices offered by various installation companies will vary, possibly significantly.

The costs used in this report are estimates based on prices charged over the last year. The table below summarizes the costs used. Costs per kWp tend to drop as the size of system increases but will be influenced by site specific costs such as the cost of any scaffolding required.

System size in kWp	Cost per kWp	Total cost
3.5 kWp	£1571/kWp	£5500
5 kWp	£1386/kWp	£6930
10 kWp	£1250/kWp	£12500
15 kWp	£1250/kWp	£18750
20 kWp and over	£1200/kWp	£24000 +

Adding a battery to the system will add to the costs. The battery cost will depend on the battery size which will need to be matched to both the solar system size and the load size and pattern. As load patterns have not been looked at in any detail the battery costs used are very rough estimates. In general, the additional cost for a battery is in the range £1500-£8000

9. Warranties

Typical warranties offered for solar systems are:

- PV panels typically have a 20 or 25 year guarantee
- Inverters usually have a 10-year guarantee
- Batteries usually have a 10-year warranty or up to 6000 cycles of charge

10. Going off-grid

Given the current high costs of electricity it can be tempting to consider going completely off-grid. While this is possible it does require careful consideration.

Not having a grid connection would require having sufficient generation capacity to supply the power needs at the highest demand time of year. This means any system will be oversized for the rest of the year. Storage capacity will be needed for short term peaks but is unlikely to cope with seasonable peaks and troughs unless it is huge. Batteries are expensive, have a significant environmental impact and are often relatively short lived.

There are a few firms which specialize in supplying off-grid systems, usually involving a combination of wind, solar and batteries.

11. Finding an installer

There are a few potential PV system installers in Cumbria and more in the North-West/North-East area. Many of them are very busy at the moment as increased energy prices are motivating many people to consider installing their own renewable energy systems.

The table below lists suppliers that we know of who are based in Cumbria or who have installed systems in Cumbria. Those suppliers highted in green at the top of the list have engaged with CAfS over the past year under the Solar Made Easy project.

You should check that any supplier you plan to use is confident they can deliver in the time scale you require and have installed systems of a similar size and complexity to your system. Using a supplier who is MCS registered is also recommend, this is normally shown on their websites.

Suppliers of Renewable systems

Company Name	Contact Name	email	Website
Eden Solar ltd	Matt Skidmore	info@eden-solar.co.uk	eden-solar.co.uk

Create Energy ltd	Stuart Richardson	hello@create-energy.co.uk	create-energy.co.uk
Cumbria Renewables	Ian Milburn	office@cumbrianrenewables.co.uk	cumbrianrenewables.co.uk
Glowsolar Ltd	Kier/Alice Marsden	hello@glowsolar.co.uk	www.glowsolar.co.uk
Love Solar	Ewen Estill	info@love-solar.co.uk	love-solar.co.uk
Power and Energy Ltd	Andy Cole	andy@powerandenergyltd.co.uk	powerandenergyltd.co.uk
SJD Electrical Services (Cumbria)	Simon Dockeray	info@sjdelectrical.com	www.sjdelectrical.com
AB Energy Centre	Ben Fischer	info@abenergycentre.co.uk	www.abenergycentre.co.uk
Greenfields Heat and Power Ltd		info@greenfieldspenrith.co.uk	www.greenfieldspenrith.com
Lakes Renewables	Ben Dyson		lakes-renewables.co.uk
Logic Group	Kevin Hall	info@logic-group.co.uk	www.logic-group.co.uk
North West Solar	James Gough	info@nwsolar.co.uk	www.nwsolar.co.uk
Roland Hill Ltd		office@rolandhills.co.uk	www.rolandhills.co.uk
RJ Solar		info@rjsolar.co.uk	rjsolar.co.uk/
Solar Style UK, Stockton on Tees		contact@solarstyleuk.com	solarstyleuk.com
Total Power Installations Ltd		simon@totalpowerinstallations.co.uk	totalpowerinstallations.co.uk

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