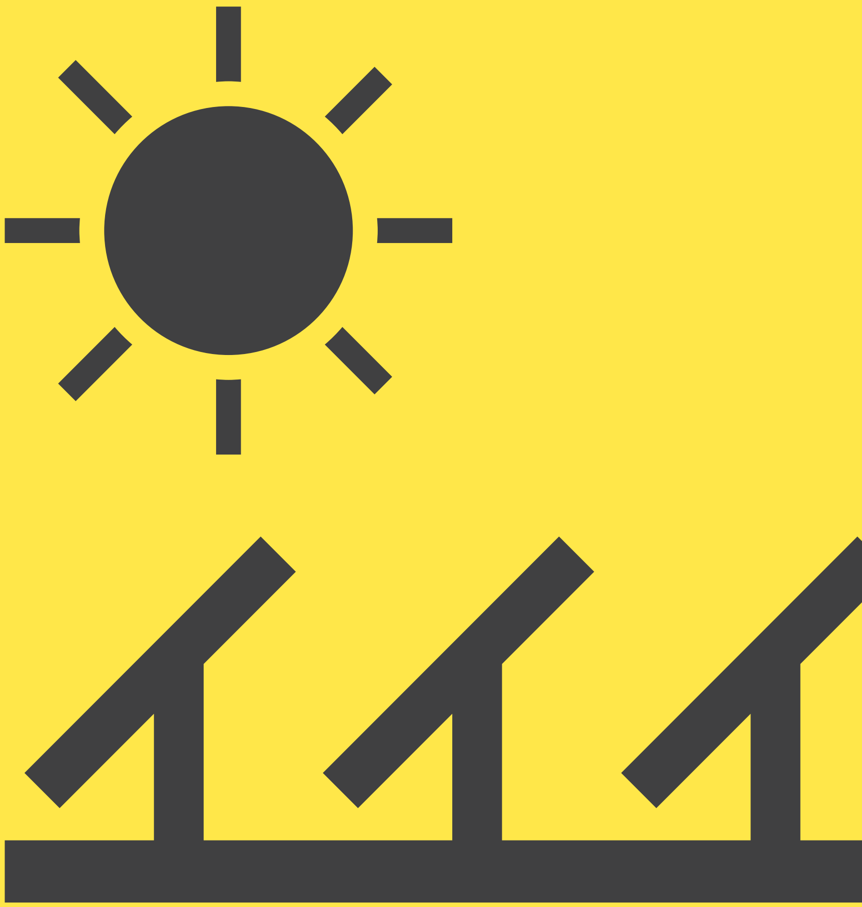
Solar Photovoltaics

A Best Practice Guide for businesses in Northern Ireland



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Executive Summary

This user friendly guide is designed to give businesses in Northern Ireland not only an introductory understanding of solar photovoltaic systems (PV's) but also satisfying those who wish to understand the more technical of aspects and to aid them in the development of a technically and economically viable project that can be integrated into their building or business. This guide provides a detailed explanation of some of the fundamental aspects of PV projects.

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Pictured above, clockwise (l-r):

Photovoltaic Solar Panels
Industrial Installation for converting Solar Energy to Electricity
Solar Panel Installation
Earn more income: Each unit of clean electricity earned 5.59p in 2013

The guide is structured to be as easy to use as possible, providing an introductory understanding in Section A Essential – The Basics, but also satisfying those who wish to understand the more technical detail and develop a feasible project in Section B Advanced – Feasibility. Where an endnote is added for further explanation it is indicated by roman numerals in superscript.

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1.0 Introduction

1.0 Introduction

Solar panel electricity systems, also known as solar photovoltaics (PV), capture the sun's energy using photovoltaic cells. These cells don't need direct sunlight to work – they can still generate some electricity on a cloudy day. The cells convert the sunlight into electricity.

Application of PVs in buildings has a very large potential and this best practice guide is focused on this area of use. Solar PV can form part of the roof structure, walls or be floor mounted. Different types will lend themselves to different buildings.

Solar PVs are not a new technology. In 1839 Alexandre Becqyuerel first observed the photovoltaic affect in a conductive solution exposed to light, and the first 'solar cell' was patented by Melvin Severy in 1894. Hoffman Electronics created the first 10% efficient solar cell in 1959 and in 1964 the Nimbus spacecraft was launched with a 470 W PV array. It took until 1999 for total, global solar installed capacity to reach 1 gigawatt peak (GWp - a million kWpi), the equivalent of a single nuclear power station. In 2012, over 36GWp of new solar capacity was installed, the equivalent of the peak of new nuclear in 1986.

The massive growth in solar over the last decade continues to accelerate, and is recognised as a global megatrend. As demand for energy grows across Northern Ireland, solar PV will play a central role in our energy mix.

CLEAN – Solar is an extremely clean form of electricity generation. The carbon used to manufacture solar panels (known as modules) is recovered within the first two to three years of operation. New production processes can reduce this to less than one year using fluidised bed reactor technology.

PROVEN – Solar is the most rigorously field-tested of all renewable energy technologies in the UK over the last decade. During the Solar PV Major Demonstration Programme (2003/05) and the Low Carbon Building Programme Phase 1&2 (2006–2010)[ii] thousands of installations were monitored across the UK including Fivemiletown High School, Lisneal College, University of Ulster and multiple schools, social housing developments and government buildings here in Northern Ireland.

RELIABLE – With no moving parts, solar has extremely high levels of system reliability and very few panel failures.

PREDICTABLE – The levels of light falling on a solar array are consistent to within 3–4% year-on-year.
The specific performance characteristics of any module and inverter combination can be calculated using highly accurate system design software.

SCALABLE – From single modules on small cabins to multi MWpiii roof-top installations, solar can be scaled to the available roof resource, energy demand or budget of a building. Historically, budget was the principal limiting factor when sizing a solar array. Since 2010, available roof resource and local network capacity constraints are the main limiting factors.

AFFORDABLE – In 2013, the electricity produced by a 50 kWp solar array in Northern Ireland fixes the cost per unit at between 7.5p and 14p per kWh for the life of the module. Solar is now competitive with the grid, albeit the cost is up front rather than as-used.

Solar is a remarkable, world-changing technology. In real terms, the price of grid-supplied electricity in Germany has not increased since 2008 due to the cost dilution effect of solar on the grid. Although major investment would be required to replicate this effect in Northern Ireland, the opportunity to future-proof our electricity mix, stabilise costs and grow jobs-rich industry is possible. Based on current rates of tariffs and support, and assuming future rises in energy prices, those businesses that invest capital to generate their own electricity on site, will gain a competitive advantage over those that do not. The impact of future price increases will be diluted enabling greater cost control. Under these circumstances, solar PV is a secure, strategic investment opportunity for Northern Ireland business.

1.1 What they do

Every solar PV system is made up of several components: solar panels (modules), inverter(s), a meter and your existing consumer unit. The process is as follows.
The sun produces radiation, even on cloudy days.
PV cells on the panels turn the radiation into direct current (DC) electricity. The current flows into an inverter, which converts the DC to alternating current (AC) electricity.
AC is compatible with the main electricity grid and most electrical appliances; it is ready to use. The current is fed through a meter and then into your consumer unit. Plug in and switch on. Your system will automatically use the free electricity you've generated and top-up from the grid as needed. Any electricity you don't use is exported to the grid for others to use. All this happens silently, automatically and without any user intervention.

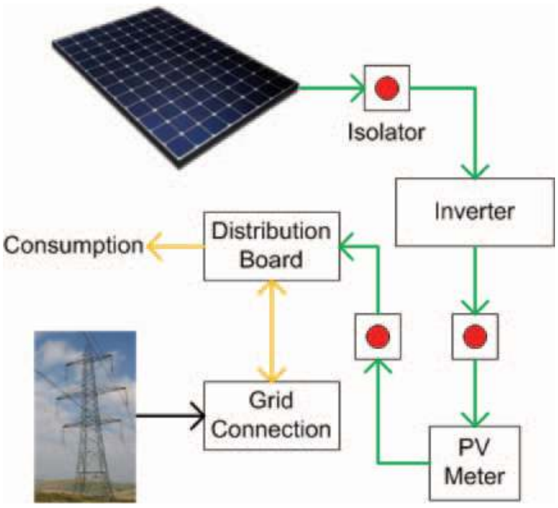

Figure 1: A typical solar PV layout
(image courtesy of Element Consultants)

1.2
Why we need them

Like most developed economies, Northern Ireland relies on fossil fuel derived electricity; primarily from coal. Global demand for energy is increasing dramatically as populations grow, energy-intensive technology and economic activity flourishes, and immature economies develop. This is happening as fossil fuel reserves diminish, albeit slowly. As a consequence, competition for finite resources is increasing.

In real terms, Northern Ireland's buying power for energy is extremely limited and so we are exposed to ever higher prices. Furthermore, 80% of the stated fossil fuel reserves will have to remain unburnt if we are to maintain a global temperature increase rate of less than 2°C this century and negate runaway climate change. As these issues converge, the role of clean energy is enhanced.

Northern Ireland's target is to reduce carbon emissions by 35% from 1990 levels by 2025. Based on current progress it appears unlikely that this will be achieved. Solar PV will form an essential part of any future reduction strategy.

Solar PV is a key technology (although no single renewable energy technology offers a 'silver bullet') because it can be applied to almost any roof that points in the right direction; it delivers electricity at the point of use rather than via the inefficient grid system; and it can be deployed rapidly.

1.3
How they make money

The economics of going solar are very simple.
Savings and income are derived from three sources:

SAVINGS – by using the clean electricity your solar system produces, you will buy less electricity from the grid and make savings on your utility bill.
As grid-supplied electricity prices increase, the savings you make will also increase.

INCOME – under the NIROCs (Northern Ireland Renewable Obligation Certificates) scheme you are paid for every unit of clean electricity you produce from the solar on your roof. The payment depends on the size of system you install. Up to 50kWp, you will be paid 4 NIROCs; larger systems over 50 kWp receive 2 NIROCs. NIROC values are set annually in October; the price at October 2013 was 4.24 pence per kWh.

A LITTLE MORE INCOME – any clean electricity not used is metered and exported to the grid.
In October 2013 each exported unit of clean electricity earned 5.59p.

1.4
How they compare to other renewables

Solar PV is simple to design, simple to install and simple to own. Because solar is simply an additional electrical supply circuit, it requires no major integration with other equipment or systems on site and can be readily added to almost any building. Solar PV is installed on almost any roof type using proven fixing systems or can be installed on the ground. Once installed, solar PV requires no planned maintenance, has no moving parts and is silent in operation. The only running cost over time is inverter replacement, which is typically a 10–15 year cycle, although extended warranties are available. Solar also has a warrantied 25–40-year lifespan, but realistically can last up to 50 years.

In summary, solar is one of the simplest renewable energy technologies to design, install and own, with a long operational lifespan and little planned maintenance.

	Solar PV	Wind	Hydro	CHP
Energy Resource Annual Variation %	3-4	20	Site Specific	Fuel Specific
Technology Maturity (Low, Medium, High)	High	High	High	Med-High
Technology Complexity (Low, Medium, High)	Low	Med	Med	High
Installation Complexity (Low, Medium, High)	Low	Med	High	High
Planning Complexity (Low, Medium, High)	Low	High	High	Med
Carbon Cleanliness (Low, Medium, High)	Med	Low	Med-Low	Fuel Specific
Project Scalability	Modular	None	None	None

Figure 2: Renewable energy comparisons

2.0 What are Photovoltaic Cells?

Cells are manufactured from a range of materials. The most significant in terms of manufactured volume is crystalline silicon (C-Si). The cells are sandwiched between two layers of tempered glass, and referred to as a laminate. When the laminated cell is exposed to light, electrons flow from the positive layer to the negative layer and create electricity.

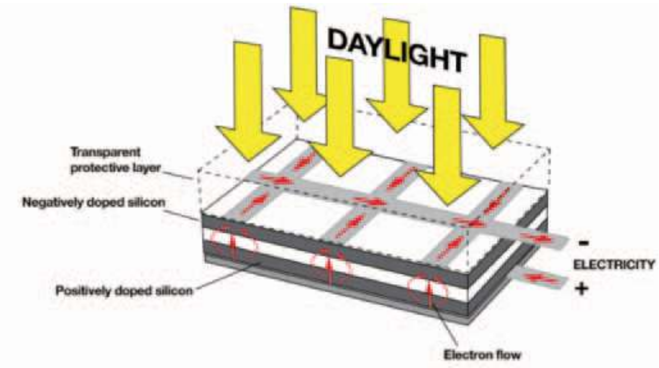

Figure 3: Cell operation (image courtesy of solarcentury.com)

There is a broad range of different PV cells produced by over 1,500 manufacturers. There are four main types of commercially available cells:

- Monocrystalline silicon PV
- Polycrystalline silicon PV
- Amorphous silicon PV
- Hybrid PV.

Monocrystalline PV and polycrystalline PV are the most common and they account for approximately 93% of all modules sold globally in large and small-scale systems. Amorphous silicon accounts for approximately 4.2% of the global market sales. The fourth type of PV cell is called a hybrid as it consists of a crystalline cell coated in an amorphous layer.

Solar panels are rated according to kilowatts peak (kWp); this is an industry standard that enables comparisons between different modules based on their performance when flash-tested with 1,000W/m2 of light under controlled laboratory conditions. The kWp rating will vary according to your budget and how much space you have available on your roof. The total amount of electricity generated over the course of a year is measured in kilowatt hours (kWh). A typical domestic solar panel system will be rated from 3–4 kWp, which will generate around 2,400 to 3,400 kWh per year respectively. The main factors affecting the output will be the specification of the equipment and the pitch and orientation of the installed system; environmental factors also play a part.

As a comparison, a typical 2-3 bedroom, 3–4 person household uses approximately 4,000 kWh of electricity per year for lights and electricity while, according to the Energy Saving Trust, an energy efficient A-rated house fitted with solar panels should be able to reduce this figure considerably.

Solar panels require daylight, not just direct sunlight, in order to generate electricity. However, output will vary in real time depending on daylight intensity and the position of the sun relative to the roof at different times of the year.

Solar panels need very little maintenance except for occasional cleaning. They have a 25- year performance warranty as standard and a typical operational lifespan of 30+ years. You should nevertheless check with your installer regarding system specific maintenance requirements before you commit yourself.

2.1 Inverters

Solar panel inverters are used to convert the DC energy produced by the solar photovoltaic panel to AC, through an automatic switching process. Grid-connected inverters are designed to match the voltage and frequency of the national grid, and set the solar supply marginally higher than the grid so that solar energy is ‘pushed’ to the nearest point of use in the building. This ensures you will always use the solar supply BEFORE the grid when there is demand in the building. If the solar is producing less energy than required, the grid tops-up automatically to ensure a consistent supply. This happens automatically, seamlessly and without any user intervention or supply disruption.

Grid-connected inverters shut down when supply is lost so do not provide back-up energy during power cuts. This safety feature protects NIE operatives from potential export from solar when working on power lines. You can buy battery back-up inverters which do supply AC electricity to selected loads in the event of a power cut and this is set to become a growth market in the next 12–18 months as customers add value to existing solar PV systems, and anticipate increased frequency of power cuts.

Figure 4: Commercial inverter bank
(image courtesy of Planet Solar (NI) Ltd)

There are numerous makes of inverter available. Leading suppliers include Kaco, SMA, Fronius and Mastervolt. These companies manufacture high quality inverters for a wide range of markets from small domestic systems to large commercial systems. They have extensive experience in the sector and are widely known for their reliability and quality.

2.2 Deterioration

NIROCs for PV are calculated for an economic lifetime of 20 years, indicating that the Department of Enterprise, Trade and Investment (DETI) believes that panels will produce for at least that long. The warranty conditions for PV panels typically guarantee that panels can still produce at least 80% of their initial rated peak output after 25 (and up to 30) years. So manufacturers expect that their panels last at least 25 years, and that the efficiency decreases by no more than 1% per year.

What makes talking about lifetimes for PV panels difficult is the fact that very few panels have been installed for long enough. In the UK, more panels have been installed between 2006 and 2008 than in all previous years together. Globally, only a small proportion of all PV panels installed are older than 10 years.

It would be wise to use 1% per annum for the deterioration rate in any financial predictions.

2.3 Servicing

There is no planned maintenance requirement:

- Self-cleaning by rainwater run-off at 5deg pitch and above
- No moving parts or consumable equipment at roof level
- Design software factors marginal impact of soiling between periods of rainfall.

Inverter replacement at year 15 should be factored into cash flow. As a general rule of thumb, assume 8% of contract value for inverter replacement; 0.4% annualised over 20 years.

3.0 PV System Components on Buildings

The modules are fixed to a building (usually the roof, but sometimes as vertical facades, louvres or glazing) using fixings at the roof interface and rails. There is a growing trend to install modules as ground-mounted arrays (where space permits, and to enable optimum pitch and orientation). BIPV (Building Integrated PV) such as solar tiles and slates provide a discrete alternative to conventional materials. BIPV has a cost premium due to relatively low manufacturing volumes and more specialist design and development costs.

Figure 5: Fixing details (image courtesy of Planet Solar (NI) Ltd)

Modules are connected in series and the DC cable must enter the building without compromising weather-tightness. The fixing detail is always specific to the roof type and specification. Inverters can be placed outside, but not in direct sunlight, and most have IP65 rating for external operation.

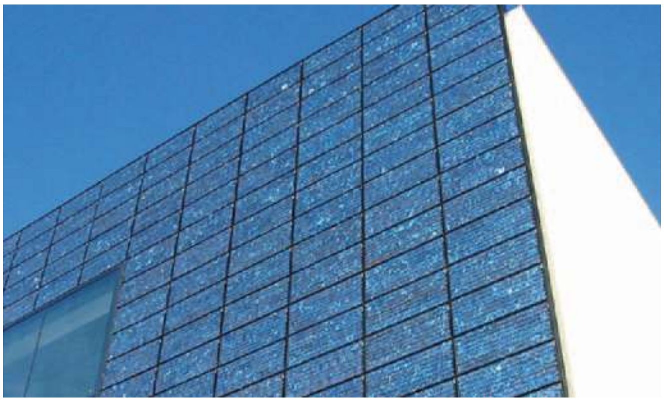

Figure 6: Solar PV cladding
(image courtesy of Planet Solar (NI) Ltd)

4.0 PV System Components in Buildings

Inverters are usually installed internally, using a fire-proof board against a vertical wall. DC cables enter the roof space and connect to the inverter, which usually includes internal DC isolation. AC cables feed a generation meter upstream of the point of connection on the distribution board. Between the distribution board and the utility main fuse an import/export meter is fitted.

5.0 Sizing

There are several factors affecting the sizing
of solar arrays.

1. To meet energy, or carbon saving targets.
2. To achieve compliance with statutory obligations (Building Regulations, Part F1 & F2 Conservation of Fuel & Power, Code for Sustainable Homes, BREEAM, iSBEM).
3. To utilise available roof resources.
4. Budget constraints: historically, budget constraints were the main focus. Since 2010, prices have become more affordable and grid-supplied electricity prices have risen so other priorities have superseded budget constraints.
5. To optimise income.
6. Grid connection restraints.

The appropriate size for any specific installation will be determined by the examination and resolution of the factors listed above.

6.0 Planning Permission

Where arrays can be designed and installed so as not to extend beyond the roof ridge line and leading edges of the roof, and mechanical fixing of the arrays can be undertaken to ensure the modules do not sit more than 200mm above the roof covering then arrays can be installed without a formal Planning Application under Permitted Development Rights, Planning (General Development) Order (NI) 1993, amendment effective 30th April 2013. This covers microgeneration which includes solar arrays up to 50kWp total capacity. Where array size exceeds this limit, a Planning Application is required. Similarly, all ground-mounted arrays, and those using A-frames on a roof require a Planning Application at present.

7.0 Grid Connection

NIE Distribution controls the grid connection process for generators in Northern Ireland and maintains a dedicated website section for the operation[iv]. They currently offer two types of grid connection; G83 applications cover single phase installations up to 3.68 kW and three phase installations up to 11.04kW; for 3.69 kW or greater on single phase, or 11.05 kW or greater on three phase you must make a G59 application.

At April 2014 G83 applications carried no application fee while G59 applications cost £651.60 up to 20 kW and £1,953.60 from 21kW to 150kW. There was a fee of £6,513.60 for arrays of 151 kW up to 2 MW.

Whereas the G83 connection process is to fit the system and then inform NIE, G59 is essentially the opposite. You need to apply with full planning permission (where applicable), and a network study will be carried out to establish if the circuit you are on needs any upgrade to take the extra load. Where network upgrades are required, NIE will provide a quote for the required works. The timescale for G59 applications is 90 days standard to get a quote, 90 days to accept or decline terms offered and, if any construction is needed, it can take between 9 and 12 months to complete.

It is important to note that G59 applications to NIE are increasing dramatically and include multiple applications for other generating technologies so the timeframes above are best-case.

8.0 Financials

8.1
Example system costs

System costs will vary widely depending on module type, array size, installation site and installation details. Below we give example costs for typical arrays using standard, good quality equipment, Microgeneration Certification Scheme (MCS) registered installers, and installed on a standard roof construction with good access. Prices range from 1.10–2.00 £/W.

Costs have fallen significantly in the last decade with dramatic decreases between 2011 and 2012, as Chinese manufacturers produced module inventory surplus to demand. This stock was ‘dumped’ onto the US and European markets at below cost prices. At the end of 2012, the US imposed import duties on Chinese sourced cells and modules and the EU followed suit in early 2013. As a consequence, module prices increased in 2013 by 8–15% as UK wholesalers and distributers pre-paid duties to maintain supply. A range of settlements have been reached so that module pricing is now relatively stable.

The expectation that costs can continue to fall may be unrealistic. Firstly, modules are one of several hardware components in a system, albeit the most expensive. Secondly, costs of transportation and distribution from source will continue to increase. Finally, the cost of designing, supplying and installing a solar array as a turnkey package is subject to the same inflationary pressure (especially on fuel, insurance, labour costs etc.) as any other capital project.

Array Size (kWp)	From (£)	To (£)
4	6,500	8,000
6.5	10,000	14,000
11	15,000	18,000
20	24,000	30,000
50	55,000	75,000

Figure 7: Example system costs

8.2
Replaced power

The greatest return on a solar PV project will be made by replacing as much of the grid consumed power as possible. The power that you consume from the grid will always be the most expensive as the cost contains not only generation costs but also transmission costs and losses. The income from the solar PV system will be made up of a combination of the value of replaced power, including VAT and levies, NIROC payments and export income.

8.3
Export income

Currently, in Northern Ireland, only Power NI offers export tariffs for small generators. For renewable energy generators up to 50 kW, Power NI publishes its prices for export in October each year and this helps you to work out the expected income you can earn for the year ahead. This means that Power NI takes the risk out of fluctuating energy prices for smaller generators and can give certainty when calculating payback periods.

The Power NI export tariff in October 2013 was 5.59 p/kWh.

Export payments are paid annually to generators of 10 kW or less – generators over 10 kW can choose a quarterly or annual payment. Payment for export will be made by Power NI directly into your bank account. A meter reader will continue to read your electricity meter so that a bill can be issued for the amount of electricity you have bought from your supplier. Power NI will contact you to request the export meter reading either at the end of each September or at the end of every quarter, depending on the size of your installation. As soon as they receive the export meter reading, they will arrange payment for you.

For larger generators a variety of power purchasers are available.

8.4
NIROCs

The Renewables Obligation is the main support scheme for renewable electricity projects in the UK. It places an obligation on UK suppliers of electricity to source an increasing proportion of their electricity from renewable sources. A Renewables Obligation Certificate (ROC) is a green certificate issued to an accredited generator for eligible renewable electricity generated within the United Kingdom and supplied to customers within the United Kingdom by a licensed electricity supplier. One ROC is issued for each megawatt hour (MWh) of eligible renewable output generated. The Renewables Obligation (Northern Ireland) Order came into effect in April 2005 and the Northern Ireland Renewables Obligation (NIRO) was introduced by DETI.

The NIRO has been subject to regular reviews and the day-to-day functions of administering the NIRO are performed by Ofgem. Ofgem, based in London, is responsible for the process of accrediting renewable energy installations and issuing NIROCs to generators in Northern Ireland. Power NI is an Ofgem agent for generators up to 50kW so it can help smaller generators to get accredited with Ofgem and to manage the ongoing NIROC administration on their behalf.

NIROCs are subject to banding; different renewable technologies of differing sizes receive a different number of NIROCs. Solar PV receives 4 NIROCs for installations up to 50 kWp and 2 NIROCs for installations greater than 50 kWp < 250 kWp. Varying levels apply above this size. The banding levels are subject to review from 2015/16 onwards.

The Power NI NIROC unit price in October 2013 was 4.24 p/kWh so, for solar PV up to 50 kWp, the payment was 16.96 p/kWh. Larger generators must negotiate their NIROC payments direct with a licensed electricity supplier. Some generators between 50 and 250 kW have succeeded in negotiating a proportion of the published NIROC rate with Power NI. Generators over 250 kW must enter the open market for NIROCs.

8.5
Calculating income and simple pay back

In September 2013, the typical unit price for electricity was 13–15 p/kWh, NIROCs were 17.64 p/kWhv, for systems under 50kWp, and export tariff was 5.41 p/kWh for systems under 50 kWp. The financial advantage of consuming generation on site as opposed to exporting is clear.

To calculate the income from a specific system you will need to know what size the system will be (to determine the NIROC band), what it will generate, how much of the generation you will export and how much you will use on site. From these figures you can calculate an average unit value (AUV) for the generated electricity as follows.

Assumptions:

1. You pay 15 p/kWh for your grid supplied electricity (including VAT and levies).
2. You expect to export 75% of the electricity you generate.
3. You are installing 4 kWp.

75% Export	%	Tariff (p/kWh)	AUV (p/kWh)
Exported electricity	75	5.41	4.06
Consumed on site	25	15	3.75
NIROC	100	17.64	17.64
		TOTAL	25.45

Figure 8: AUV for 75% export

This gives you an AUV of 25.45 p/kWh or 0.2545 £/kWh. If you were to export only 25%, the AUV would increase to 30.24 p/kWh.

75% Export	%	Tariff (p/kWh)	AUV (p/kWh)
Exported electricity	25	5.41	1.35
Consumed on site	75	15	11.25
NIROC	100	17.64	17.64
		TOTAL	30.24

Figure 9: AUV for 25% export

There is a good simple online calculator for solar PV called PV-Watts that will give you an initial estimate of generation and income once you have established an AUV. Follow the instructions below:

1. Click on http://rredc.nrel.gov/solar/calculators/pvwatts/version1/
2. Select the button for Europe and then GBR Belfast from the drop down list.
3. Click on “Start PV Watts for International Sites”.
4. The data for Belfast is already loaded, the kW is set to 4, the derate factor is set to 0.77 and the array type is set to Fixed Tilt; leave these unchanged.
5. Set the Array Tilt to the pitch of your roof. We’ll use 35 degrees here.
6. Set the Array Azimuth to the direction your roof faces. We’ll use south.
7. Enter your AUV in the energy cost box in £/kWh.

You should see the output below.

Station Identification	
City:	Belfast
Country/Province:	GBR
Latitude:	54.65° N
Longitude:	6.22° W
Elevation:	81 m
Weather Data:	IWEC
PV System Specifications	
DC Rating:	4.00 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.08 kW
Array Type:	Fixed Tilt
Array Tilt:	35.0°
Array Azimuth:	180.0°
Energy Specifications	
Energy Cost:	0.2545 £/kWh

Results			
Month	Solar Radiation (kWh/m2/day)	AC Energy (kWh)	Energy Value (pound)
1	0.91	74	18.83
2	1.63	128	32.58
3	2.55	238	60.57
4	3.49	312	79.40
5	4.95	451	114.78
6	4.45	386	98.24
7	4.14	368	93.66
8	3.89	347	88.31
9	3.16	278	70.75
10	2.00	175	44.54
11	1.12	89	22.65
12	0.65	47	11.96
Year	2.75	2892	736.01

Figure 10: PV Watts output (image courtesy of NREL)

Thus, from a 4 kWp system, you might expect annual earnings of £736.01.

Simple pay back is the length of time that it will take for you to recover your costs. For a solar PV system, the costs are the installation costs and the annual maintenance costs. As we have seen above, in most cases, the maintenance costs are simply the cost of replacing the inverters every 15 years. Thus in most cases the simple pay back, in years, will be:

$$\text{Simple Pay Back} = \frac{\text{Capital Cost}}{\text{(Replaced power value + NIROC value + Export value)}}$$

Thus, using the capital cost for a 4 kWp system in Section 8.1, simple pay back will be achieved in just over 10 years for this system. Note that this is a purely hypothetical example.

8.6 Optimising returns from solar PV

Getting the best return from your solar PV system will depend on several factors. The main considerations are listed below:

1. Carry out a site survey to understand your project potential.
2. Plan the project carefully.
3. Ensure the system is professionally designed either by an MCS accredited installer or an independent consultant.
4. Ensure you carry out your own calculations for generation and pay back. Do not rely on the installer’s illustrations.
5. Ensure you fully understand what you will realistically generate and get paid.
6. Ensure the system is regularly monitored post installation.

B. Advanced – Feasibility

9.0 Site Survey

9.1
Introduction

The site survey is undertaken to establish the factors affecting the feasibility of an installation. Each factor is discussed below and each will affect the final design, cost and ultimate feasibility. Indeed, any one of the factors may stop the project in its tracks. As a first step, you will need a layout of the building roof structure and its dimensions. This can be a simple sketch but, if you have suitable computing resources in house, modern geographic information systems (GIS) are more useful. Spatial NIvi is an online resource of both maps and vertically orientated aerial photographs. The site includes measuring and annotation tools. The picture below shows a chicken shed annotated with measurements from Spatial NI.

Figure 11: Spatial NI example (image courtesy of Spatial NI)

9.2
Pitch and orientation of available roof resources

The quantity of solar energy received by the panels depends on the orientation of the panels in relation to the sun. As the maximum amount of the sun's energy is received on the earth when the sun is at its highest (solar noon on the summer equinox) the optimum orientation of the roof will be due south. Additionally, the maximum energy will be received by the panels when they are at right angles to the sun. This roof inclination, or pitch, varies with latitude. In Northern Ireland, the optimum summer pitch is 39–40 degrees (measured from horizontal).

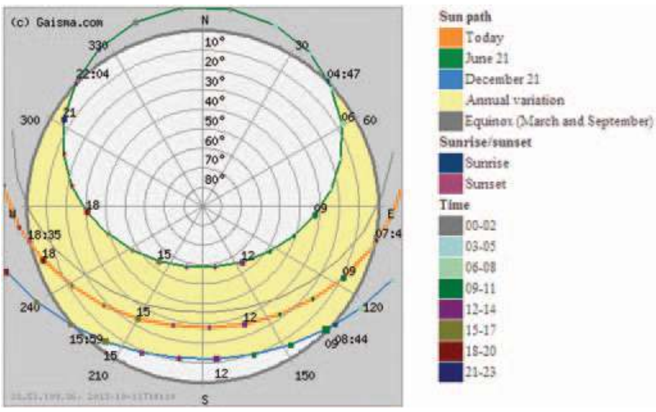

Figure 12: Sun path for Belfast
(image courtesy of Gaisma.com)

Accurate knowledge of both pitch and orientation will ensure that the solar energy calculation is correct for the project. You can create your own sun chart onlinevii for a full understanding of the solar path during the year for your specific location.

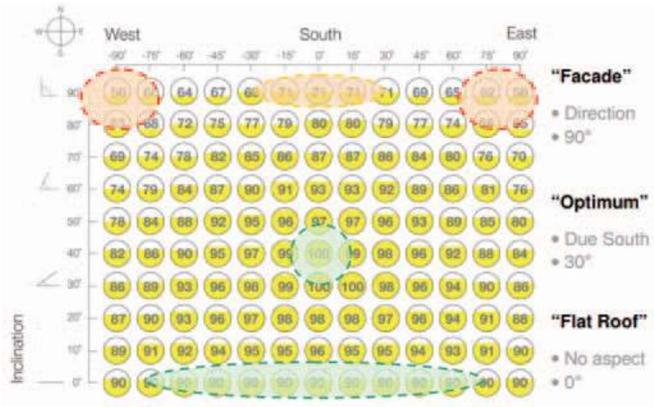

Figure 13: Solar irradiation, azimuth and inclination
(image courtesy of solarcentury.com)

A standard compass, an online map, or a traditional clock face with 12 pointing north will give you the orientation of the building. If the eaves of the roof can be easily accessed, the pitch (slope or inclination) of the roof can be measured easily by holding a piece of cardboard against the eaves, ensuring the base is level and lined up with edge of the roof. The roof slope is then marked on the cardboard and the angle measured with a protractor. If the roof is not accessible but the line of the roof slope can be viewed from the ground, there are smartphone apps available for measuring angles. A standard theodolite may also be employed.

9.3
Useable area of roof resources

Wind loads affect the safety of the PV installation and the roof and roof structure must be capable of withstanding the predicted loads. BRE Digest 489viii gives a simplified method for determining the dynamic wind pressure for use in determining the design wind load according to BS6399-2. The design wind load is greatest at the edges of the roof area parallel to the eaves and verge so it makes sense to leave these areas clear. Calculations are given for the edge zone sizes based on the building height and length, the wind direction and the type of roof constructionix. As a rule of thumb, the clear area depth for the eaves of duo pitch roofs should be at least one tenth of the roof length. This may be breached by increasing the concentration of fixing points and then ensuring the roof structure can accommodate the wind uplift pressure; following assessment by a suitably qualified structural engineer. Final design of the mechanical fixing of the arrays should be in accordance with BRE Digest 489 – 'Wind Loads on roof-based Photovoltaic systems', and

495 – 'Mechanical Installation of roof-mounted Photovoltaic systems'. LABC (Local Authority Building Control) publishes a useful best practice guide on retrofitting solar panels with regard to roof loading[x].

9.4
Potential for near and far shading impact

Shade makes a big impact on the performance of a PV system. Even a small degree of shading on part of an array can have a very significant impact on the overall array output. Shade is one element of system performance that can be specifically addressed during system design – by careful selection of array location, equipment selection and layout and in the electrical design (string design to minimise shade effects).

There are various methods for assessing shade de-rating. The MCS methodology (used by all MCS accredited installers) is relatively complex; there are two separate calculations, one for shading closer than 10m and one for more distant shading. Both involve sketching the obstacle onto a sun path diagram and calculating the cumulative effect[xi]. This method is complex and designed for standardisation within the MCS system. It is considerably easier to use one of the available apps although they come at a cost[xii]. An example of a shade report from an app is given below.

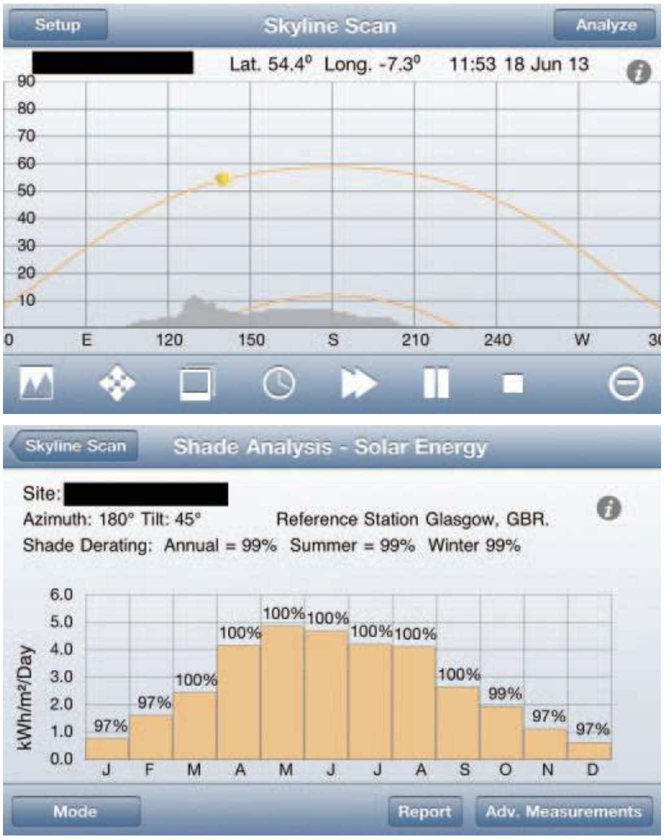

Figure 14: Shading report
(image courtesy of Solmetric Inc)

Shading from objects adjacent to the array (for example: vent pipes, chimneys, and satellite dishes) can have a very significant impact on the system performance. Even a small amount of shading can have a big impact on generation. As modules are connected in a series of 'strings', the performance of the string is limited by the lowest performing module in that string. Where such shading is apparent, either the array should be repositioned out of the shade zone, or where possible the object casting the shade should be relocated.

9.5
Roof covering, construction and condition

Make a detailed survey of the roof. Pay particular attention to the condition of covering (slates, tiles etc.), understand the construction (rafters, purlins, wall plates, etc.). The age and condition of the roof have a direct bearing on the project. As roofs age the covering weathers and becomes more fragile; fixings such as nails and tingles rust or loosen and the underlying structure ages; battens rot in time and older felts become brittle and tear easily. If the roof is old, any disturbance may disturb unseen problems and, as solar PV installers are not roofers, you may find that installation of the PV system creates problems with the roof. If you are in any doubt whatsoever have the roof examined by a qualified surveyor prior to proceeding. It may well be the case that the roof is approaching the end of its useful life and should be replaced prior to (or concurrent with) installing solar PV. Note that if you are considering roof repairs, re-roofing or an extension in the foreseeable future, it may well be worth organising the works in conjunction with each other.

9.6
Term of existing roof guarantees

If the roof you are considering using is less than 20 years old it may be covered by a guarantee. Fitting a solar PV system will involve fixing the modules mounting system through the roof covering. This will penetrate the roof and could invalidate any guarantee; especially on a flat roof. You should ensure that you understand the restrictions imposed by any guarantee and engage with the guarantee provider to evaluate any restrictions. It may be the case that an adjusted or extended warranty can be provided after the installation is complete.

9.7
Site safety – roof access restrictions

Working on roofs is a high risk activity because it involves work at height. Roofers account for 24% of all workers who are killed in falls from height. There several laws relevant to roof work safety[xiii] and planning for safety is essential.

The Health and Safety at Work Act 1974 is supported by more specific legislation such as the Management of

Health and Safety at Work Regulations (MHSWR) 1999. Construction and design specific legislation, e.g. the Construction (Design Management) Regulations 2007[xiv] (CDM), ensures the design of safe systems of work. These regulations apply to health and safety management and require the identification and elimination of hazards during all phases of design and construction, during operation, maintenance and eventual decommissioning.

The legal responsibilities of the designer are now extremely onerous; furthermore it is a legal responsibility of the client to ensure that the designer understands and is made aware of their legal duties as a designer. This becomes a particular problem when foreign contractors are employed.

All those who work in the construction industry have their part to play in looking after their own health and safety and in improving the industry's health and safety record.

A CDM client is someone who is having construction or building work carried out, unless they are a domestic client. A domestic client is someone who lives, or will live, in the premises where the work is carried out. The premises must not relate to any trade, business or other undertaking. Although a domestic client does not have duties under CDM, those who work for them on construction projects will.

On all projects clients will need to:

- Check competence and resources of all appointees
- Ensure there are suitable management arrangements for the project welfare facilities
- Allow sufficient time and resources for all stages
- Provide pre-construction information to designers and contractors.

Where projects are notifiable under CDM 2007, clients must also:

- Appoint a CDM co-ordinator
- Appoint a principal contractor
- Make sure that construction work does not start unless a construction phase plan is in place and there are adequate welfare facilities on site
- Provide information relating to the health and safety file to the CDM co-ordinator
- Retain and provide access to the health and safety file.

A notifiable project is one where there is more than 30 days on site or more than 500 man days of resource involved. It is unlikely that projects less than 250 kWp will constitute a notifiable project but nonetheless CDM will apply. Before you give the go ahead to start on site you should have complied with the CDM requirement to appoint a competent contractor.

The Management of Health and Safety at Work Regulations 1999 (MHSWR) impose a duty of care on the client to ensure that all systems of work are safe and that employees are safe, insofar as is reasonably practical.

The installations should therefore be subject to:

- Provision and Use of Work Equipment Regulations 1998 (PUWER)
- Electrical Safety
- Control of Substances Hazardous to Health Regulations 2002 (COSSH).

Hazard identification and risk assessments will be required at the very least and thus CE marked for the systems.

Assess the available access for scaffold and edge protection erection. Assess the roof construction for weak or fragile areas. Assess the route from the entrance to the site to the place of work for the purpose of carrying equipment and materials to the place of work. Consider areas where access requirements and working patterns may conflict and assess the solution. Once a plan is in place, make a risk assessment of the entire plan and adjust as necessary.

9.8
Electricity supply infrastructure

The size of the solar PV array that you install will be influenced by the electricity supply infrastructure. You should verify the type of supply that you have on site; single phase (two cables) or three phase (three cables) as this will dictate what you can install without incurring connection costs and connection delays. See Sections 7 and 15 for more detail.

You should also examine your existing metering arrangements. Grid connections are allocated according to Meter Point Reference Numbers (MPRN). This can be very useful if you have more than one metered three phase supply. Where a 50kWp array might appear to be the optimum installation, if two MPRNs are available locally, two 11.04kWp G83 arrays (one at each MPRN), would avail of the simple connection arrangements and avoid the delays, costs and uncertainties inherent in the G59 process.

Note that it may be cost effective to connect to a nearby three phase supply line but this can only become clear once a grid connection offer has been made. Unlike the GB system, there is no opportunity to assess the grid infrastructure and likely costs of connection prior to applying to NIE.

9.9
Earth and bonding arrangements

Arrays up to 50 kWp must be designed and installed in accordance with the MCS publication: Guide to the Installation of Photovoltaic Systems[xv]. In practice, those over 50 kWp will need to meet the same standard.

Protective equipotential bonding is a measure applied to parts of the electrical installation which, under fault conditions, may otherwise have a different potential to earth. By applying this measure, the risk of electric shock is limited as there should be little or no difference in voltages (potential difference) between the parts that may otherwise become live. These parts are categorised as either exposed-conductive-parts or extraneous-conductive-parts.

In most PV systems there are no parts that are considered to be an exposed-conductive-part or extraneous-conductive-part, therefore protective equipotential bonding is not usually required.

On the DC side of the PV installation the designer should select double or reinforced insulation as the protective measure and therefore the component parts of the installation will be isolated and will not require protective equipotential bonding.

9.10
Inverter location

Inverters are normally wall mounted. They generate heat and must be provided with sufficient ventilation. Clearance distances as specified by the manufacturer should be observed. Inverter locations such as plant or boiler rooms, or roof spaces prone to high temperatures, should be avoided, if possible, to avoid the risk of overheating. Overheating can cause a loss in system performance as the inverter will de-rate (work less efficiently) when it reaches its maximum operating temperature. This should be highlighted within the operation and use manual left with the customer and ideally a label instructing them not to block ventilation should be placed next to the inverter. Ensure the installer finds good locations for the inverters bearing in mind that access will be required to change them in future.

9.11
DC/ AC cable runs

Where possible, identify cable runs that already exist in the building. Use existing cable trays where they are present to ensure new wiring co-locates with existing services where it can be easily accessed. If there are specific cable containment requirements on site, ensure that they are identified and followed. Protection for the cable from the inverter(s) must be provided at the distribution board. This protective measure shall be specified and installed in accordance with the requirements of BS 7671.

9.12
System performance monitoring

There is a variety of system monitoring options available depending on your requirements. These range from simple generation displays to full data monitoring solutions with online portals and data evaluation. From a business perspective the online portals can fulfil two functions; enabling data evaluation and providing a good marketing tool displaying the company's green credentials.

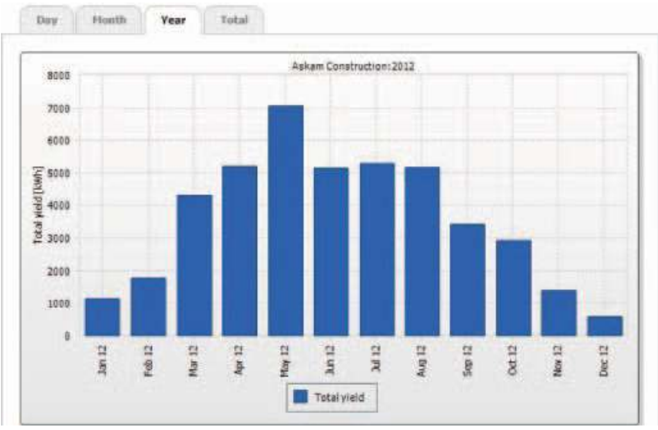

Figure 15: Typical monitoring display
(image courtesy of Planet Solar (NI Ltd)

A useful recent addition to the range is the Wattson Solar Plus[xvi]. This system visually displays the generation and use but also allows you to control non-essential electrical items so that they only activate when spare generated electricity is available.

10.0 Solar PV Cell Types

10.1
Monocrystalline silicon PV

To produce monocrystalline silicon a crystal of silicon is grown from pure molten silicon. This single crystal cylindrical ingot is cut into thin slices between 0.2 and 0.3mm thick; this is the basis of a solar PV cell. The edges are cut off to give a hexagonal shape so that more can be fitted onto the module. These PV cells have efficiencies of 13–17% and are the most efficient type of the three types of silicon PV cell. However, they require more time and energy to produce than polycrystalline silicon PV cells, and are therefore slightly more expensive.

10.2
Polycrystalline silicon PV

Polycrystalline silicon is also produced from pure molten silicon, but using a casting process. The silicon is heated to a high temperature and cooled under controlled conditions in a mould. It sets as an irregular poly- or multi-crystal form. The square silicon block is then cut into 0.3mm slices. The typical blue appearance is due to the application of an anti-reflective layer. The thickness of this layer determines the colour; blue has the best optical qualities as it reflects the least and absorbs the most light. More chemical processes and fixing of the conducting grid and electrical contacts complete the process. Mass-produced polycrystalline PV cell modules have an efficiency of 11–15%.

10.3
Amorphous silicon PV

Amorphous silicon is non-crystalline silicon. Cells made from this material are found in pocket calculators etc. The layer of semi-conductor material is only 0.5–2.0μm thick, where 1um is 0.001mm. This means that fewer raw materials are necessary in their production compared with crystalline silicon PV production. The film of amorphous silicon is deposited as a gas on a surface such as glass. Further chemical processes, the fixing of a conducting grid and electrical contacts follow. These PV cells have an efficiency of between 6 and 8%. Multi-junction amorphous thin film PV cells with each layer sensitive to different wavelengths of the light spectrum are also available. These have slightly higher efficiencies.

10.4
Hybrid PV

Hybrid photovoltaic cells are classified as PV cells that use two different types of PV technology; e.g. a monocrystalline PV cell covered by an ultra-thin amorphous silicon PV layer. The advantage of this type of cell is that it performs well at high temperatures and maintains higher efficiencies (18%+) than conventional silicon PV cells. However, these cells come at a cost premium.

The cells are usually arranged into ‘modules’, each generating power ranging from 10 watts to 300 watts. Individual panels are arranged in arrays. The silicon acts as a semiconductor, which generates an electrical charge when exposed to light. This charge will a be DC, so panels need an inverter situated inside the building to convert this charge into 240V AC and there should also be a display unit within the building which enables you to monitor the performance of the panels.

11.0 Inverter Types

There are numerous makes of inverter available. Recognised manufacturers include Danfoss, Fronius, Kaco, Mastervolt, Power One, Samil, SMA, Solar Edge, Solar Max and Steca. These companies manufacture high quality inverters for a wide range of markets from small domestic systems to large commercial systems.

When selecting an inverter, it is important to ensure the manufacturer's design software is used to ensure compatibility with the specific module and the array design you intend to install. All inverters include a five-year product warranty as standard. Most manufacturers offer extended warranties in five-year increments up to 20 years; it is worth considering these when procuring a system. Performance monitoring options also vary between manufacturers; so these should be reviewed.

Most inverters designed for commercial-scale solar PV applications have 96–98% efficiency.

There is a growing trend towards the use of micro-inverters, which convert DC to AC at the module, and optimisers which balance the load of individual modules. This is relatively new system design architecture and initial results are promising. Micro-inverter based systems include sophisticated monitoring of individual module performance. The main manufacturers are Enecsys and Enphase, and many of the above manufacturers of string inverters are now introducing micro-inverters. At present, string inverters have a lower cost per kWp installed and 2–3% higher efficiency. Micro-inverters are typically sold with a 20- year warranty, and have been operating in the field for approximately three years in the UK. As micro-inverters are installed behind individual modules, replacement in the event of failure is likely to be complex and expensive in the case of roof-mounted arrays.

12.0 Solar Irradiance

12.1
Introduction

Solar PV cells respond to direct, diffuse and reflected radiation. Direct radiation comes directly from the sun, reflected radiation may come from the ground or other reflective surfaces and diffuse radiation is diluted by cloud cover and other diffusers. All three combine to make up the solar energy resource.

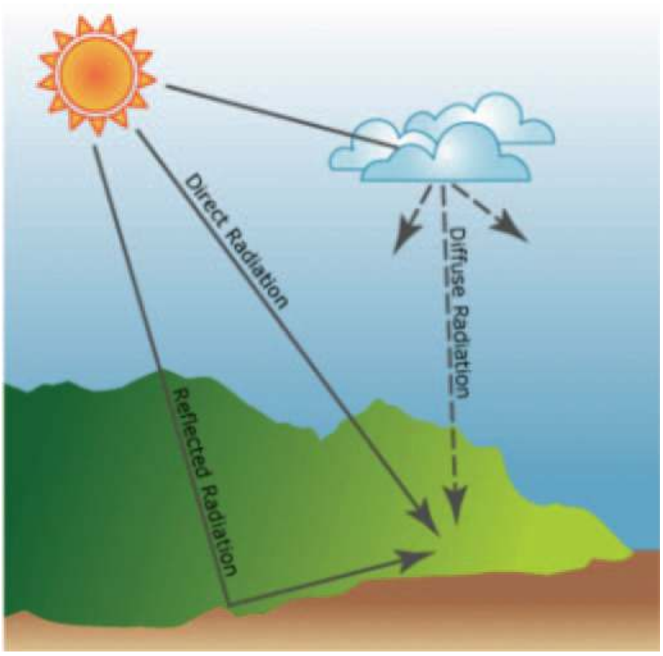

Figure 16: Solar irradiation

12.2
Data sources

There is a range of climatic data available that can be used to predict solar PV system performance. The main sources of data used in the UK are the Microgeneration Certification Scheme[vii], PV-GIS (the EU data portal)[xviii] and the software program PVSol Pro[xix]. All of the sources take their data from measured historical data subsequently remodelled through computer analysis.

MCS is an industry led certification scheme for microgeneration products and installation services supported by the Department of Energy and Climate Change (DECC). The scheme gives irradiance data, as per the MIS3002, v.3.1; zone 21 covers Northern Ireland. The data set can be downloaded in the form of a spreadsheet and will give the specific yield (kWh/kWp/a[xx]) of a notional PV installation anywhere in the UK. Thus, in the example shown below, for a building orientated +25 degrees from south (205° on a compass) with a roof pitch (slope or inclination) of 25° we should expect to generate 815 kWh (units of electricity) per kWp (per kW of installed power) per annum.

	Orientation (variation from south)					
Slope	**0**	**5**	**10**	**15**	**20**	**25**
20	812	812	810	808	805	802
21	815	815	814	811	809	805
22	819	818	817	815	812	808
23	822	821	820	818	814	810
24	825	824	823	820	817	813
25	827	827	825	823	820	815

Figure 17: MCS generation
(image courtesy of MCS)

So, if we were considering installing a 20 kWp system, we would expect to generate 16,300 kWh per annum in a good clear site.

PV-GIS is an online resource funded by the EC Joint Research Centre that provides specific yield calculations from user input data. To use the system follow the instructions below.

1. You will need the GPS co-ordinates of your site for the most accurate result. If you have them skip steps 2 and 3 below.
2. Click on http://www.howtocreate.co.uk/php/gridref.php
3. Scroll down and enter the site grid reference, press tab and read off or copy the GPS coordinates in DD format.
4. Click on http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php#
5. Enter the GPS co-ordinates and press search. The map zooms into your location.
6. Enter the correct slope and azimuth for the roof, adjust the other variables as necessary and click Calculate.

Using the same roof as we did for the MCS data, for a location at 54.607799°, -6.412947° we get an annual specific yield of 848 and a yield of 16,960 kWh for a 20 kWp system. More usefully, as shown below, the calculation is shown for each month and these figures may be used when calculating financial projections.

Fixed System: inclination = 25°, orientation = 25°				
Month	E_d	E_m	H_d	H_m
Jan	0.78	24.2	0.95	29.6
Feb	1.46	40.9	1.80	50.3
Mar	2.35	72.8	2.94	91.2
Apr	3.47	104	4.46	134
May	4.00	124	5.23	162
Jun	3.76	113	4.98	150
Jul	3.42	106	4.55	141
Aug	3.06	94.9	4.05	125
Sep	2.46	73.7	3.17	95.0
Oct	1.48	45.9	1.87	58.1
Nov	0.92	27.6	1.14	34.3
Dec	0.68	21.0	0.83	25.8
Yearly average	**2.32**	**70.7**	**3.00**	**91.4**
Total for year	**848**		**1100**	

Figure 18 PV-GIS generation
(image courtesy of EC JRC PV-GIS)

PVSol Pro is an expensive software programme but the manufacturers conveniently give an online calculator for the UK using SAP 205 and SAP 2009 methodology at http://www.solardesign.co.uk/sappv/sappv2005-9.php This is fairly crude but gives a useful comparison of 821.60 kWh/a for a 1 kWp system or 16,432 kWh per annum for a 20 kWp system.

Although the PV-GIS result is highest, it is location specific. However, the online calculator allows you to adjust the system losses to increase or decrease output. Use this to bring the output into line with the MCS method (in the current example 17.5% system losses) and record the monthly results (you can copy them straight into an excel spreadsheet). This will be the most useful data for financial calculations. Remember to allow for the shading de-rating identified in Section 9.4 above.

13.0 Electricity Consumption

13.1 Introduction

As we discussed previously, income from solar PV comes from three sources; replaced electricity, export and the NIROC scheme. Income from the NIROC scheme is earned on all generated metered electricity regardless of how it is used. Replaced electricity on site will always have a higher value than exported electricity. The difference in value will depend, amongst other factors, on the size of your system. Export tariff will be dictated by whether or not you have a fixed export tariff with Power NI (<50 kWp) or an agreed tariff range with a licensed electricity supplier under a Power Purchase Agreement (>50 kWp). For a system <50 kWp, the export tariff was 5.59 p/kWh in October 2013 and, as the standard domestic electricity tariff with Power NI was approximately 15p/kWh plus VAT[xxi] at the same time, replaced electricity is worth approximately three times as much as exported electricity. Clearly, the optimum earnings will be from a system where all of the energy generated is consumed on site.

Generation from solar PV only occurs during daylight hours which vary from summer to winter and throughout the year. Thus, unless you operate your business to match the changing daylight hours and size the system so that you always use all of the electrical output, you will not use all of the electricity generated.

To get a clear understanding of how much the system will earn, you must understand how much of the generated electricity you will consume on site and how much will be exported. To do this, you must thoroughly understand your electrical profile.

13.2 Profiling

13.2.1 Half-Hourly Metering

An electricity load profile describes the pattern of electricity use over time. The time period will vary depending on the amount of metered data available.

If your business has half-hourly metering[xxii], the load profile can be very detailed; some electricity suppliers provide on-line tools that can show you the profile over varying time periods so most of the work will be done for you. Typical tariff banding is divided between weekends, night, summer day, winter day and winter peak. By combining the data on a spread sheet you can produce useful charts. The charts below show an actual case for a factory working weekdays only.

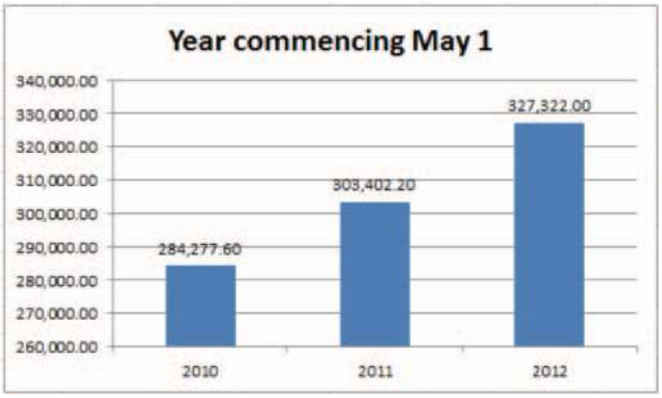

Figure 19: Annual consumption
(image courtesy of Element Consultants Ltd)

In this case we can immediately see that consumption has increased annually by 7–8% so we should allow for that increase in future projections.

Profiling by tariff band shows us that the majority of consumption is during summer day tariff which matches nicely to the highest output of the solar PV system.

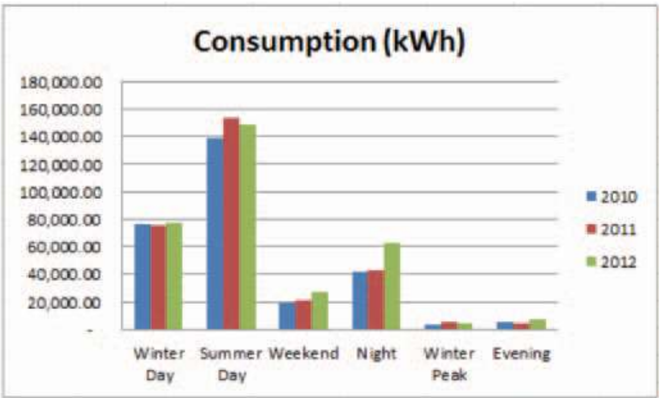

Figure 20: Consumption profile
(image courtesy of Element Consultants Ltd)

Note also the 2012 increase in consumption during the night and weekends. In this case the factory only operates during the weekdays so the chart flags up a change of use outside working hours in 2012 that should be identified and rectified.

The factory has fixed working hours and holidays and this enables us to calculate the mean power loadsxxiii. The mean power loads may be calculated by dividing total consumption (kWh) by working hours and subtracting the idle (weekend and night) load. This gives an annual active load for 2012/13 of 39.53 kW.

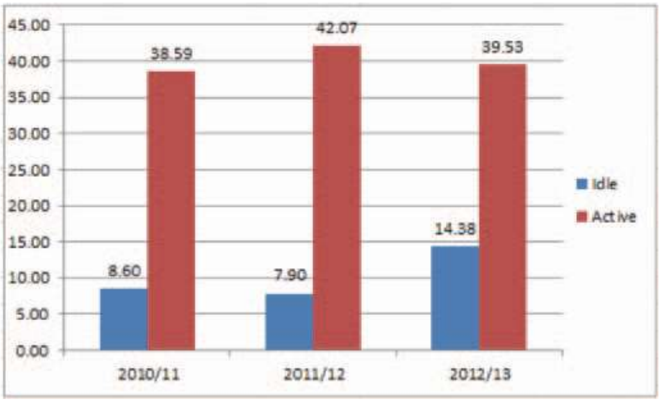

Figure 21: Mean power loads
(image courtesy of Element Consultants Ltd)

Thus, while the power requirement has reduced during working hours, it has doubled during idle hours. As idle hours represent 75% of time this is a substantial waste of resources and money. The night and weekend load can be further divided to give a day time load and, subsequently, a day time consumption that roughly correlates to the solar PV daily generation period. It will be impossible to correlate exactly as generation increases and decreases with cloud cover and ambient temperature.

	kW	Hrs/ week	kWh/yr
Work Day load	39.53	41	84,282
Night & W/E load	14.38	127	94,933
W/E Day load	14.38	18	13,460
Night load	14.38	109	81,506

Figure 22: Consumption matched to generation
(image courtesy of Element Consultants Ltd)

This consumption profile may now be applied to the expected generation. Note that all consumption profiles vary and you will need to adjust your calculations for your specific site.

13.2.2 Standard Metering

Without half-hourly metering, profiling is less accurate. Billing will normally be monthly and the invoice will show metered consumption. However, it is commonplace for service providers to allow long periods of estimated readings. You must be aware that estimated readings will not assist you in profiling and will be misleading. If you do not have meter readings it will be wise to allow a period of at least six months (preferably a year) for you to undertake a thorough meter reading schedule to establish your profile.

If the business has a day and night/weekend tariff, the calculations are simplified slightly. Again, if you have the monthly consumption data and you know the working and idle hours, you can use the method above to calculate the idle and working hours and the subsequent proportions of daytime hours and the relevant loads and consumption.

If the business is on a single tariff, the only way to establish a load profile, apart from very regular meter reading, is as follows:

- Make a complete list of electrical appliances.
- Record the electrical load of each appliance.
- Estimate the hours that they operate for each day of the week.
- Separate the working hours between day and night.
- Multiply the load by the day and night hours for each appliance.
- Sum the day and night hours separately.
- Check that this correlates to your meter readings and adjust as necessary.

13.3 Calculating on-site consumption

In Section 12 above we have seen that PV-GIS gives us outputs per day and per month from systems of specific sizes. From this we can calculate the output per month for an array of any size (a). From the annual day time consumption calculated in Section 13.2.1 we can calculate the monthly day time consumption (b) and subsequently the percentage of own use generated each month (c). From PV-GIS we know the maximum generation per day for each month (d). From the loads in Section 13.2.1 we can calculate the minimum own use per day; weekend day time (e). If the maximum generation per day is greater than the minimum use per day, the excess generation will be exported. The table below shows the calculation for a 50 kWp array at the example factory used in Section 13.2.1. Where the ‘Min Use as a % of Max Prod’ (f) is less than 100%, excess electricity will be exported on non-workdays (h). The quantity of electricity exported will be (d – e) x h.

50 kW								
Generation kWh	**Own Use kWh**	**% of own use**	**Max generation /day kWh**	**Min Use/day kWh**	**Min Use as a % of Max Prod**	**Workdays**	**Non Workdays**	**Export kWh**
a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**
997	8301	12.01	32	129	403.13	24	7	
1800	7498	24.01	64	129	201.56	21	7	
3350	8301	40.36	108	129	119.44	22	9	
4810	8033	59.88	160	129	80.63	23	7	217
5880	8301	70.84	190	129	67.89	23	8	488
5560	8033	69.21	185	129	69.73	21	9	504
5200	8301	62.64	168	129	76.79	24	7	273
4520	8301	54.45	146	129	88.36	22	9	153
3360	8033	41.83	112	129	115.18	22	8	
2120	8301	25.54	68	129	198.71	24	7	
1230	8033	15.31	41	129	314.63	21	9	
807	8301	9.72	26	129	496.15	23	8	
39634	**97737**						**40**	**1635**

Figure 23: Calculating own use and export
(image courtesy of Element Consultants Ltd)

This method will deliver a reasonable estimate of on-site consumption and exported electricity.

There are many other methods for estimating quantities of exported electricity. An alternative is presented below.

1. Overlay electricity tariff timings on a location specific sun chart (www.gaisma.com).
2. Record generating hours (daylight) for each tariff.
3. Calculate tariff specific generating hours per month.
4. Convert to a percentage of the monthly total generating hours.
5. Download annual sunshine hours per day and check and adjust.
6. Multiply by the monthly generation from PV-GIS.

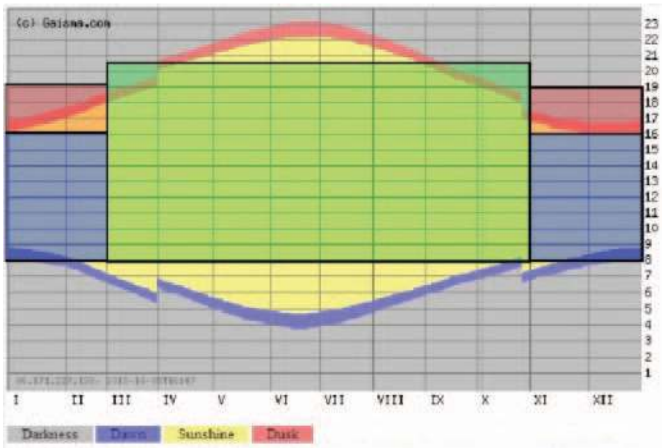

Figure 24: Sun chart overlaid with tariff times
(image courtesy of Gaisma.com & Element Consultants Ltd)

14.0 System Design

14.
System Design

In the past, system design was an extremely complex process with significant engineering expertise required to match modules, inverters and cable sizes. As the market has grown, design software has greatly simplified system design processes; assuming accurate data is used. However, experience and expertise remain important to ensure good design standards are achieved. Since 2010, and the introduction of FiT in GB, off-the-shelf system kits have been offered to installers of domestic-scale systems. This approach has extended to commercial-scale installations. This one-size-fits-all approach reduces costs, but may compromise absolute system performance and value over the system operational lifecycle. Below are some key design considerations when selecting an installation contractor.

Module and inverter specification: you can expect the installers you invite to bid for your project to explain how their equipment is the best available; the manufacturers and wholesalers they work with are expert at differentiating products in the market. Ask for in-field performance data for Northern Ireland, and ask for a copy of the predicted performance issued with the original contract to see how the two compare. Beware if this data is not forthcoming.

Roof interface: the installation of solar should not compromise the weather-tightness of your roof, or the structural integrity of the building. There are fixing systems designed for almost any roof type, and many are designed by roofing manufacturers (e.g. Sarnafil, Kingspan, Kalzip). Ensure that the proposed fixing methodology is compatible with your roof covering, and does NOT void any existing roof guarantees. Similarly, ensure the proposed installation will be subject to a structural survey and sign-off by a suitably qualified structural engineer. It is imperative that the roof can accommodate the mass-loading of the installed system (with additional snow-loads factored) but also that the roof can withstand the uplift from wind-pressure loading of the PV system. This is one of the areas where the complete system kit approach is limited, unless the system has been designed for the particular roof in question.

14.1
Kilowatt peak (kWp) rating

The kWp rating of an array is an industry standard means to make reasonable comparisons between different systems, e.g. 200 x 250W modules would provide a 50 kWp array. The Watt rating of a module is based on flash-testing under laboratory conditions which provides a reliable means to compare module output. However, kWp does not factor the specific performance of modules and inverter(s), nor reflect the string design applied, nor the pitch and orientation of the installation. In real terms, a well-designed 40 kWp array using high quality components could outperform a 50 kWp array where poor quality design and components were used, if both were installed side by side on the same roof.

As the market for commercial-scale solar has grown in Northern Ireland over the last 1–2 years, it is assumed that ‘all solar is created equal’, irrespective of components and design standards. As a general rule of thumb, higher cost modules use higher grade cells (these are ranked A-D, with A being the highest and most consistent quality) with more rigorous quality control as evidenced by post production testing. The same applies, to a degree, to inverter units where higher quality components combined with in-house software and firmware development tend to cost more. (See Figure 25 below)

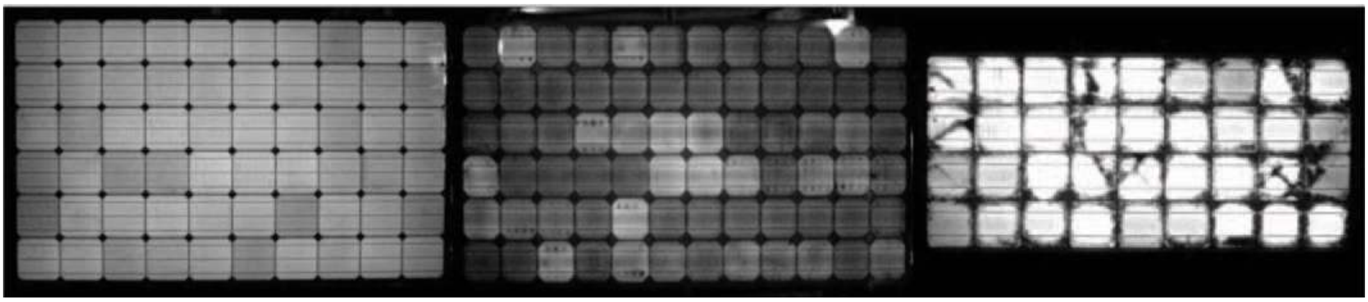

Figure 25: The good, the bad and the ugly
(image courtesy REW Solar AG)

14.2
Losses

Commercial-scale solar should use manufacturer specific design software which simplifies much of the design process. However, the quality of the final design is entirely dependent on the quality of data input which should accurately and comprehensively reflect site conditions. There are usually 2–4% losses of energy when DC is converted to AC by the inverter (this loss is dissipated as heat, so inverter location is a key consideration to minimise losses). Furthermore, there are typically 0.5–1% losses of energy through the cables between the array, inverter and point of connection to the main site supply. These losses are managed by sizing both DC and AC cables appropriately. Although design software calculates the cable specification in order to predict losses, cable length is critical to this so a comprehensive and accurate survey with cable routes recorded is essential.

14.3
Drawings

Drawing sets should be issued for approval pre-installation, and then re-issued ‘as-built’ post installation. Drawing sets are standard practice in the construction industry and serve as evidence of site-specific system design. A typical drawing set will include an electrical schematic for the complete system (as per BS7671; The Wiring Regulations 17th Edition), a module layout drawing, roof fixing detail and string design. An electrical schematic is a minimum requirement of the MCS scheme.

15.0 Understanding Grid Connection

15.1 Micro-generators

Connection for micro-generators is the simplest option. The installer should apply to NIE on your behalf completing a G83 connection pack and including:

a. G83 SSEG Commissioning Confirmation

b. G83 test results

c. A schematic diagram

d. Technical information on the hardware

e. G83/1 Certification for the inverters used

f. A site layout plan.

There is no charge for this connection. Once the application has been processed an import/ export meter is fitted. Average connection time from application to connection is 1–2 months. Because of the system size (below 3.68 kW single phase and 11.04 kW three phase) connection would be immediate on test and commissioning. The installer would complete a G83 notification for NIE's records but connect without advance approval.

15.2 Small-scale generators

The connection process and options for small-scale generators are more complex. There are two options at the outset.

The first is for a feasibility study and is available to anyone at any time. For generators of up to 150 kW the feasibility study costs £651.60, for generators over 150 kW the study is £1303.20 (prices correct at April 2014). A feasibility study is an optional study providing indicative costs for your generation connection to help you to develop your business plan. This is typically carried out before you make a formal application to the Department of the Environment Planning Service to obtain approval for your generation scheme. The study indicates the current capacity available, details of the work required to provide connection, connection voltage level and the connection point to the NIE network.

The second option is a network connection and capacity study which is a full application process offered to customers who have obtained all permissions, including planning permission at the date of application. This study is a full technical appraisal and requires you to submit a formal application (NIE Generator Questionnaire) and the full electrical technical specification of the generator being connected together with the appropriate non-refundable fee. These fees are: <=20 kW £651.60; <=150 kW £1,953.60; >150 kW <2 MW three phase £6,513.60 (prices correct at April 2014). This is the full connection application and reserves capacity on the grid.

The G59 connection is a nine step process as follows:

1. Online registration at www.nie.co.uk/genconnect/register.asp
2. Questionnaire completion and return
3. NIE reviews application
4. NIE issues formal terms and conditions and quote
5. Applicant formally accepts quote and pays – NIE initiates legalities.
6. NIE provides Generator Connection Agreement
7. Applicant advises NIE of Generators Trading Arrangement
8. Applicant returns signed connection agreement and signed certification
9. NIE countersigns Generator Connection Agreement and paralleling commences.

If NIE does not require planning permission for the installation, timescales are as shown below.

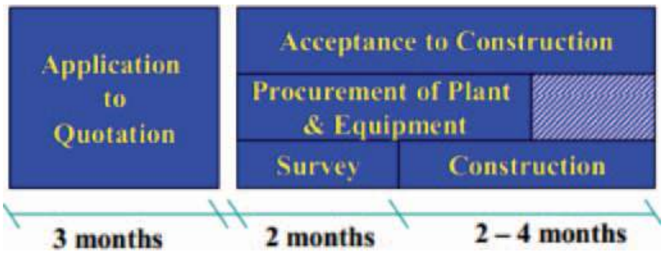

Figure 26: Grid connection – no planning
(image courtesy of NIE Ltd)

If planning permission is required the timescale is extended as follows.

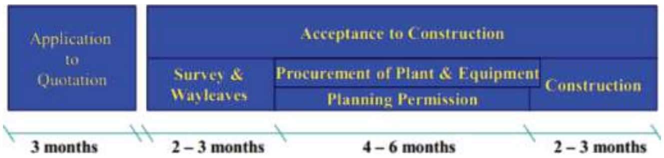

Figure 27: Grid connection – planning required
(image courtesy of NIE Ltd)

Average connection time from application to connection is 9–12 months but up to 15 months must be allowed for grid connection. Note that in some areas the grid has reached capacity and, although NIE will issue an offer, it will carry a caveat with an indefinite delay until funding and network strengthening has been undertaken. NIE publishes a Network Heat Map[xxiv] describing the condition of the network in your substation area. This gives a good indication of the possibility of gaining a connection offer without a caveat.

15.3
All generators

The generator must sign a Parallel Generator Agreement. The relevant clauses are that there is no liability for compensation of any loss of profit. Loss due to physical damage is limited to the value of the generator's installation or £100,000; whichever is the lower. NIE may de-energise the facility at any time to inspect or effect alterations, maintenance, repairs or additions to any part of the NIE system and the agreement may be terminated at six months' notice.

You will be required to enter into a Power Purchase Agreement with your power purchaser. The agreement governs the sale of exported electricity. A typical agreement is known as an SEM[xxv] Energy and Renewables Benefits Agreement. The key points are as follows:

The seller's obligations are:

- Comply with the Renewable Obligation (Northern Ireland) Order 2009 (RONI)[xxvi], comply with all regulations, insure all plant, sell all exported electricity and associated benefits to the buyer.
- Contract term is five years.
- Any new benefits arising under the agreement to be split 50:50.
- Payment made two months after generation month.
- No VAT.
- Give notice of maintenance events.
- No assignment without agreement.
- Termination: normal clauses – insolvency, non-payment etc.

The buyer's obligations reflect those of the seller. The key points are that there is a minimum two month time lag between generation and payment for generation which will affect cash flow on completion of the installation, and that the agreement cannot be assigned without the buyer's agreement.

You should be aware that the system operated by NIE can cause high connection quotes to be issued for small-scale generators. The system is operated on a first come, first served basis and offers are valid for 90 days. Thus if your neighbour puts in an application before you he will be quoted for the initial line upgrade. Subsequently you will be quoted for the greater upgrade to take the greater load. This will continue until the first quote expires. At that stage the initial upgrade (the least expensive one) becomes available again. This has led to high costs for line upgrades being quoted in the offers being issued. Additionally, the current grid infrastructure, especially in the north-west, is close to capacity. It is now common for grid connection offers to be issued with a caveat stipulating that until NIE receives agreement for a funding mechanism for additional network reinforcement from the Utility Regulator, and that work is undertaken, no connection can be made.

Clearly, microgeneration connection will always be the preferable option in terms of cost, time and simplicity. Even for systems with greater output, in the current circumstances, it would be wise to avail of the G83 capacity in the first instance and, after connection, apply for the balance required; treating the whole system as two projects.

Size	Phase	NIE Type	Requirements	Process	Costs
<= 3.68 kW	Single	Microgeneration	G83 application	Fit & Connect	No app. fee
<=11.04kW	Three	Microgeneration	G83 application	Fit & Connect	No app. fee
3.68 - 11.04kW	Single	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £651.60 All NIE costs
11.04 – 20kW	Three	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £651.60 All NIE costs
21 - 150kW	Three	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £1953.60 All NIE Costs
150 - 2000kW	Three	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £6513.60 All NIE Costs
<=5MW	Three	Small	Bespoke		
>5MW	Three	Large	Bespoke		

Figure 28: Connection Options (Prices Correct at April 2014)

16.0 Selecting Contractors

16.1 Introduction

Although, well designed and well installed solar PV should require minimal intervention over its lifetime, when you install a PV system you are entering into a long term arrangement. You expect the PV system to be operational for at least 20 years, so it is logical that you will require the company that installs the system to be operating throughout that lifetime to solve any problems that might occur. Whilst you cannot guarantee that the company will always be there for you, there are some steps that you can take to protect yourself. The Centre for Sustainable Energy provides a useful checklist of 'Questions to ask installers'[xxvii].

16.2 Micro Certification Scheme

The Microgeneration Certification Scheme (MCS)[xxviii] is an internationally recognised quality assurance scheme, supported by the government. MCS certifies microgeneration technologies used to produce electricity and heat from renewable sources.

MCS itself is a BS EN ISO/IEC 17065:12 Scheme and was launched in 2008. MCS certifies microgeneration products used to produce electricity and heat from renewable sources. MCS also certifies installation companies to ensure the microgeneration products have been installed and commissioned to the highest standard for the consumer. The certification is based on a set of installer standards and product scheme requirements.

MCS covers electricity generating technologies with a capacity of up to 50 kW. All installations of Solar PV up to 50 kWp must be installed by an MCS registered installer using MCS registered equipment to be eligible for government incentives.

The MCS should give the consumer some peace of mind as the scheme places quality standards on both equipment and installation. However, it would be naïve to think that no company operating under the scheme ever failed to meet those standards so it would be wise to put other checks in place.

16.3 Long-term company viability

In today's electronic information age, it is relatively simple to gather information about a company. You will be making a sizeable investment and you should ensure that the company is financially sound and has some organisational depth should they suffer manpower issues in the future. Any company that has traded for a couple of years will have made financial returns which are available from Companies House for a small fee[xxix]. Ask companies how they are structured and how they will manage if one of their key people drops out. Ask for this information to be included in any tender (see Section 16.6).

16.4 Examples and references

Any company that has a good track record will be more than happy to provide you with references and examples of work they have carried out. Don't be afraid to ask for at least three examples. You need to see work that is similar to the work you are asking to be carried out. Check the references you have been given; go and visit the sites and talk to the site managers. Ask them searching questions to ensure you have a full understanding of any problems that have occurred and how they might affect you. Ask for this information to be included in any tender (see Section 16.6).

16.5 Servicing arrangements

Although very little servicing is envisaged, it is a good idea to have an annual health check by the installer so that any issues are addressed and any possible issues are foreseen. The income from the system is dependent on it operating correctly so an annual health check including a visual and electrical inspection should be included in the contract. Ask for this information to be included in any tender (see below).

16.6 Tendering

Preparing a tender document and putting the work out to tender allows you to get everything that you require down on paper. The great advantage of this method of getting prices is that all the tenderers will be pricing for the work that you specify and not for what they think you want. This does not mean that you have to specify the nuts and bolts of the system. On the contrary, it is quite common for a tender to ask the tenderer to design and specify a system for a specific site, show his calculations and explain why he has chosen that system for that site. The tender can then require the tenderer to supply other items such as MCS certification, financial information, references, servicing arrangements, payment details etc.

All tenders issued for solar PV systems should include a section ensuring that the contractor is responsible for completing all regulatory approval and certification, especially any required for payment of NIROCs. The final payment for the job should be linked to the final approval. Tenders are usually written by Quantity Surveyors or independent consultants.

17.0 Funding and Financial Assistance

17.1
Introduction

In the current environment, with the demise of the banks as we have historically understood their function, funding is a fast moving and changing field. Traditional bank funding has become difficult to secure; in the case of some specific banks funding is all but absent. Some banks continue to lend for renewable energy ventures but they are looking for excellent returns and security.

Therefore, it is all the more important that you thoroughly investigate the financial variations of the scheme and have a well prepared business plan and a thorough understanding of the scheme before approaching a funding source.

17.2
Carbon Trust interest free loans

The Carbon Trust continues to make four year, interest free loans[xxx] available to all Northern Ireland businesses excluding some agricultural or fisheries businesses; incorporated businesses must have been trading for 12 months and non-incorporated businesses for 36 months. The loans are unsecured and government funded. Loans are available from £3,000–£400,000 based on the quantity of carbon emissions saved by the project.

The Carbon Trust supplies an online calculator for estimating the carbon savings and subsequent loan that might be made available at http://www.carbontrust.com/media/47185/calculator-max-loan.xls

For the 50 kWp system used previously the maximum loan available would be £12,822 over four years.

17.3
Venture capital funding

Venture capital funding should be considered as an alternative to bank lending. Often, if a loan is available, decision making, paper work and issuing of the loan will be considerably simpler than the bank system. However, you must bear in mind that any venture capital financing company will be looking for a good return and an exit strategy. They may be less flexible than banks if things go wrong. Among others, current players in the market are Nationwide Corporate Finance Ltd[xxxi] and Portman Asset Finance[xxxii].

17.4
Rent a roof schemes

Since the introduction of incentives, there have been a number of organisations offering free solar PV systems.

A company installing free solar PV panels for you will usually get the income from the generation and export tariffs for the site, while you, as the customer, will get the benefit of reduced energy bills through some of the electricity generated being used on site. But some companies offer the generated electricity at a discounted price, rather than free, so do check. If you are considering an offer of free solar PV, you should work out what the annual benefit to you will be.

The company installs the solar panels on south, south-west or south-east facing roofs. The company pays for the installation, connection charges and the maintenance of the panels. The business owner benefits from free or discounted electricity from the panels. Any electricity that is not used is exported into the local electricity network. Any income associated with this is likely to go to the installation company. As the owner of the solar panels, the installing company receives the full NIROC income.

Before committing to a rent a roof scheme ensure you fully understand the consequences. The Centre for Sustainable Energy publishes a good leaflet covering some of the questions you should ask[xxxiii]. Once the panels are on the roof you are committed to at least a 20-year relationship with that company and, should you wish to sell the property, you may find that the contract affects the value or saleability of the property. Remember that companies offering a rent a roof scheme are making money from your roof!

The Energy Saving Trust has compiled a list of all the companies[xxxiv] that, to their knowledge, are offering free solar PV. Please note that they do not recommend any particular company; they have not done any assessment of the companies on this list or their offers; and they do not assume any liability for any actions of the companies on the list. You should also check that any company or product is certified by the Microgeneration Certification Scheme and is a member of the Renewable Energy Consumer Code[xxxv].

17.5
NIROCs

All renewable energy generated earns the Northern Ireland Renewable Energy Obligation Certificate (NIROC). Solar PV installations < 50 kW earn 4 NIROCs; at October 2013 16.96 p/kWh generated. From 50 kWp to 250 kWp they earn 2 NIROCs. Banding levels above this power output vary and are available on the DETI website[xxxvi].

Ofgem issues NIROCs to renewable generators based on the metered output figures. Generators sell their NIROCs either directly to electricity suppliers or to ROC traders who sell on to electricity suppliers. The electricity suppliers present their ROCs to Ofgem to fulfil their Renewable Obligation. As the Obligation is higher than the available ROCs, suppliers must also pay buyout fees to make up the difference in their obligation. The buyout fees make up a buy-out fund that is redistributed to the electricity suppliers according to their proportion of ROCs. In this way, ROCs have a value to electricity suppliers that is at least the buyout price plus the anticipated buyout fund redistribution per ROC.

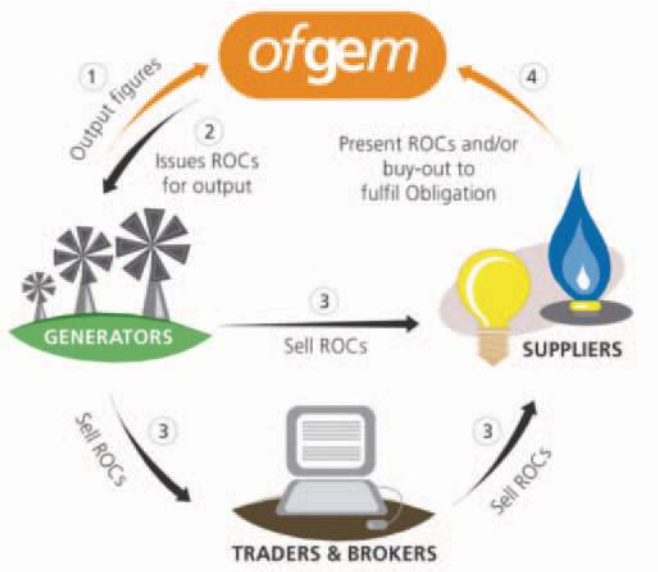

Figure 29: How ROCs work
(image courtesy of ofgem)

The buyout price is calculated by Ofgem annually along with the Obligation. A supplier's obligation, in respect of the electricity that it supplies to customers, increases every year. The price per ROC is increased in line with the Retail Prices Index annually. The trend in increase of the obligation, together with that of the buyout price, are summarised in the table below:

Obligation period (1st April - 31st March)	Buy-out price (per ROC)	% Increase	Obligation for Northern Ireland (ROCs/ MWh)	% Increase
2009-2010	£37.19		0.035	
2010-2011	£36.99	-0.54	0.0427	22.00
2011-2012	£38.69	4.60	0.055	28.81
2012-2013	£40.71	5.22	0.081	47.27
2013-2014	£42.02	3.22	0.097	19.75

Figure 30: ROC and buy-out trend

Thus, the price paid by Power NI to generators <50 kWp, for whom it acts as agent, is based on their forecast of ROCs that they will receive during a year and the quantity of electricity they will supply.

The open market price of ROCs may be checked at http://www.e-roc.co.uk/trackrecord.htm

The NIRO will close to new generation in March 2017 but all accredited generators at that date will receive the NIROC for 20 years (to 2037).

17.6 Electricity Market Reform; Feed-in Tariff and Contracts for Difference

As part of the UK wide Electricity Market Reform (EMR) DETI intends to make two specific changes to the current incentive scheme:

a. The introduction of a small-scale (<5MW) feed in tariff (FIT); and

b. The introduction of a Feed-in Tariff with Contracts for Difference (FIT CfD) for large-scale generators.

It is proposed that the enabling powers to introduce a small-scale FIT will be introduced in DETI's forthcoming Energy Bill with an intended implementation date in 2015/16. There are no further details on the scheme at present and the response to the Energy Bill – Policy Consultation has yet to be published.

For large-scale generators (>5MW), long-term contracts to encourage investment in new, low-carbon generation will be introduced. These are called Contracts for Difference (CfDs). CfDs work by stabilising the prices received by low-carbon generation, reducing the risks they face, and ensuring that eligible technology receives a price for its power that supports investment. CfDs also reduce costs to consumers by capping the price that consumers pay for low-carbon electricity; requiring generators to pay money back to consumers when electricity prices are high.

This is achieved by paying the generator the difference between a measure of the cost of investing in a particular low-carbon technology (the 'strike price') and a measure of the average market price for electricity (the 'reference price'). The generator participates in the electricity market, including selling its power, in the normal way.

The CfD system will be a competitive system. Renewable energy developers will bid for CfDs, initially on a 'first come, first served basis', subsequently in one of two annual allocation rounds. The CfD budget will be fixed. Once the budget is oversubscribed, the CfD allocation will become competitive; the least expensive projects will secure CfDs thereafter.

The CfD system will be introduced to Great Britain in 2014 but will not be introduced to Northern Ireland until, at the earliest, 2016.

18.0 Financials

18. Financials

The following list of financial tools will allow you carry out all of the financial predictions required for analysing the investment. When combined with a short-term and long-term cash flow you will have all you require for approaching a bank for financing.

18.1 Predicting income

In Section 13 we established methods for predicting both generation used on site and export quantities. To calculate the predicted income we need to apply those quantities to the relevant earning rates. Solar PV panels installed in Northern Ireland earn income in a variety of ways. The panels will be connected to a distribution board and the energy generated will be used on the premises before any is exported. This allows the owner to replace electrical energy that he would have paid for. This replacement, combined with the maximum NIROC payment is the most cost-effective method of installation and will usually lead to the fastest pay back.

The spill (export) rate that will be achieved will depend on the size of the array. For arrays up to 50 kWp, Power NI will act as the agent and you will avail of their annual published tariff (at September 2013 5.41 p/kWh[xxxvii]). For arrays over 50 kWp the energy companies now negotiate spill rates directly with the client. Power NI, Energia, Airtricity and ESB all purchase energy in the Single Energy Market (SEM). The purchase price depends on whether a 'floor price' (minimum guaranteed price) is included in the contract. A contract including a floor price might expect to be paid 85% of a combination of the SEM pool price for NIROCs plus LECs[xxxviii] plus the NIROC buyout. A contract excluding a floor price might receive 90–95%.

You should note the advantages of installing a system below 50 kWp; firstly, you will avail of double the NIROC payment; secondly, you will not have to deal with Ofgem for accreditation; and thirdly you will avail of the published Power NI spill rate. These advantages are not inconsiderable; they make the process much simpler and less time consuming.

If the predicted monthly generation is applied to the electricity tariffs, NIROC rate and export tariff, the predicted income may be calculated. The example below is for the 50 kWp array described in Section 13.3. (see Figure 31 below)

Month	NIROC	Export Tariff	Own Use	NIROC Income	Export Income	Own Use Income	INCOME
	p/kWh	p/kWh	p/kWh	£	£	£	£
Jan	17.64	5.41	17.42	175.87	-	173.68	349.55
Feb	17.64	5.41	14.71	317.52	-	264.78	582.30
Mar	17.64	5.41	12.92	590.94	-	432.82	1,023.76
Apr	17.64	5.41	12.99	848.48	11.74	596.63	1,456.85
May	17.64	5.41	13.29	1,037.23	26.40	716.60	1,780.23
Jun	17.64	5.41	13.61	980.78	27.27	688.12	1,696.17
Jul	17.64	5.41	13.40	917.28	14.77	660.22	1,592.27
Aug	17.64	5.41	13.52	797.33	8.28	590.42	1,393.02
Sep	17.64	5.41	13.25	592.70	-	445.20	1,037.90
Oct	17.64	5.41	13.32	373.97	-	282.38	656.35
Nov	17.64	5.41	15.13	216.97	-	186.10	403.07
Dec	17.64	5.41	17.35	142.35	-	140.01	282.37
Total	**17.64**	**5.41**		**6,991.44**	**88.45**	**5,176.96**	**12,256.85**

Figure 31: Predicted income

Having established the income we can define the AUV as the income (£12,256) divided by the generation (39,634 kWh) or 30.93 p/kWh. At more than twice the price being paid for electricity this is very good value. However, the AUV also allows us to compare the value of different systems. Remembering that NIROC rates change over 50 kWp, a larger system will have a smaller AUV.

18.2
Capital and annual costs

Capital costs will be specific to the installation. Module types vary widely and prices vary accordingly. High output modules such as Sunpower are considerably more expensive than standard monocrystalline panels such as the Sharp ND-R250A5. Similarly roof integrated panels will be more expensive to install than roof mounted panels; depending on the specification of the work undertaken. Inverter prices will vary and cabling and protection prices will be site specific. In each case, quotations should be received from at least three reputable contractors.

There is no planned maintenance requirement:

- Panels are self-cleaning by rainwater run-off at 5deg pitch and above.
- No moving parts or consumable equipment at roof level.
- Design software factors marginal impact of soiling between periods of rainfall.

Inverter replacement at year 15 should be factored into cash flow. As a general rule of thumb, assume 8% of contract value for inverter replacement; 0.4% annualised over 20 years.

18.3
Pay back

Section 8.5 described how to calculate simple pay back. To calculate pay back allowing for annual costs we need to include the amortised cost of the inverter replacement over say a 20-year life span. In this case the equation will be:

$$\text{Pay Back} = \frac{\text{Total Capital Cost}}{(\text{Annual Income}) \times (1 - (\text{Annual Cost} / \text{Annual Income}))}$$

Using the 50 kWp example above the result would be 6.02 years.

This equation may be expanded to allow inflation and utility inflation to be added to the variables.

18.4
Carbon savings

The Carbon Trust publishes Carbon Conversion Factors online[xxxix]. The document includes an embedded spread sheet to enable you to calculate carbon emissions from grid generated electricity. In the example above the array is predicted to replace 39,634 kWh of grid electricity. Using the 2013 spread sheet this equates to 17,535.87 kgCO2.

18.5
Total return

The total return on investment is straightforward. It tells the investor the percentage gain or loss on an asset based upon his purchase price. To calculate total return, divide the selling value of the investments plus any income received by its total cost. In essence, this works out to capital gains plus dividends as a percentage of the money you laid out to buy the investment.

$$\text{Total Return} = \frac{\text{Total Income}}{\text{Total Cost}}$$

Again, using the 50 kWp example above, the total income over 20 years divided by the capital cost plus 20 years of annual costs is 2.97.

18.6
Equivalent interest

The equivalent interest rate is the actual annual rate of return that you receive on an investment over the life of an investment when it is compounded. Thus, any competing investment would need to be able to exceed the equivalent interest rate. It may be calculated by the equation:

Equivalent Interest Rate = ((Total Return^(1/Lifetime))-1) X 100

Thus, in the 50 kWp example above the equivalent interest rate is 5.59%.

18.7
Cost per kWh

Of the financial indicators, cost per kWh is one of the most useful. If you are trying to compare the relative merits of different schemes or technologies you can compare the cost per kWh of each to see which has the lowest cost per unit of energy generated. This may be useful for comparing, say, solar PV and a wind turbine or for varying PV array sizes. It may be calculated by the equation:

Cost/kWh = (Lifetime Costs / Lifetime Generation) X 100

Thus, in the 50 kWp example above the cost per kWh is 10.42 p/kWh.

18.8
Net present value

Net present value (NPV) is a formula used to determine the present value of an investment by the discounted sum of all cash flows received from and expended during the project. The NPV tells you what the investment is worth to you today. To calculate the NPV you need to know all of the cash outflows and incomes for the project lifetime along with the discount rate. The discount rate is the interest rate that you expect to apply over the lifetime of the project and the amount by which a future receipt or expenditure will be discounted to bring it to present value. The current UK government discount rate is 3.5%. NPV may be calculated by the equation:

$$NPV = -C0 + \frac{C1}{(1 + r)} + \frac{C2}{(1 + r)2} + \ldots\ldots + \frac{CT}{(1 + r)T}$$

Where –C0 is the initial investment, C1 is the cash flow in year one, r is the discount rate and T is time (in years).

Thus, in the 50 kWp example above the NPV is £95,262.

We should note that no allowance has been made for utility rate inflation or inflation. Both of these factors will considerably increase the NPV.

18.9
Sensitivity analysis

A sensitivity analysis allows you to adjust certain parameters in your financial calculations to see what effect it will have on the outcome. For instance, you might wish to examine what happens to your pay back if the cost of electricity rises by 10%.

The simplest way to execute sensitivity analyses is to use one of the freely available sensitivity analysis add-in toolkits for Excel available on the internet.

19.0 Project Management

19.1
Introduction

Fortunately, of all the renewable energy technologies, solar PV is probably the simplest to manage. The project management can be further simplified by using the tender process. Tenders should be used to ensure that as much of the responsibility for the job as possible is placed on the contractor. Tenders are normally written by Quantity Surveyors or independent consultants.

19.2
In-house capabilities

Having read this guide and carried out the site assessment you should have a fairly good understanding of what is required. You should also have an idea of what type and size of system you might install. It may be that your business has the ability, in-house, to carry out the planning and preparation for the work. However, the preparation of a tender by a competent third party is likely to be money well spent. If you choose to use in-house resources, you must also ensure that the capability is available to carry out the project management as a priority. Issues in construction projects normally require instant answers to resolve them.

19.3
Planning the project

Each project will be different so no two project plans will be the same but certain factors will be common to all projects.

- Business work patterns; you will want to arrange the installation so that it has the minimum impact on your daily trading activity. The installation of cable runs and inverters internally may be disruptive or create dirt in a clean environment. The installation of panels externally may require access via loading bays etc.
- Weather will be a deciding factor when it comes to the installation of the panels on a roof. As we have seen working at height is dangerous; rain makes roofs slippery. Thunderstorms and heavy rain will prevent work progressing.

When planning the project you should set specific milestones. The milestones will depend on the size of the project. For a project >50 kWp you might use the grid connection offer as a milestone whereas for smaller systems that will not be relevant.

Once milestones have been identified a full timetable may be drawn up.

Glossary

AC ..... Alternating current

Accredited generator ..... A generator that has completed the accreditation process with Ofgem

Amorphous silicon ..... is the non-crystalline allotropic form of silicon. It can be deposited in thin films at low temperatures onto a variety of substrates.

Array ..... A collection of modules

AUP ..... Average unit price

AUV ..... Average unit value

Azimuth ..... An azimuth is an angular measurement in a spherical co-ordinate system. The azimuth is the angle formed between a reference direction (for PV south) and a line from the observer to a point of interest projected on the same plane as the reference direction.

BIPV ..... Building Integrated photovoltaics

BREEAM ..... BRE Environmental Assessment Method; a method of assessing, rating and certifying the sustainability of buildings.

BS6399-2 ..... Loading for Buildings. Part 2 Code of practice for wind loads.

BS 7671 ..... Requirements for electrical installations

Carbon savings ..... In this case the amount of carbon saved by replacing grid electricity with solar PV generation.

CCL ..... Climate Change Levy; is a tax on energy delivered to non-domestic users in the United Kingdom. Its aim is to provide an incentive to increase energy efficiency and to reduce carbon emissions.

Cost per kWh ..... The cost of an investment per unit of energy generated over its lifetime.

DC ..... Direct current

DETI ..... Department of Enterprise, Trade & Investment

EMR ..... Electricity Market Reform; UK wide reform of the market

EN 45011 ..... Guide for the accreditation of bodies operating certification of products

Equivalent Interest ..... The actual annual rate of return that you receive on an investment over the life of an investment when it is compounded.

Export tariff ..... The rate paid for exported electricity; also known as spill tariff.

FIT ..... Feed in tariff; incentive system for renewable generation currently used in Great Britain, due for implementation in Northern Ireland after 2015/16

FIT CfD ..... Feed in tariff with contract for difference; proposed method of incentives for large -scale projects in Northern Ireland after 2016.

G83 connection ..... Grid connection for up to 3.68 kW single phase or 11.04 kW three phase

G59 connection ..... Grid connection for all connections greater than G83 criteria

GIS ..... Geographic Information System

HHM ..... Half-hourly metering; where an electricity meter is automatically read every half hour and the data is recorded.

Hybrid PV ..... These systems combine a photovoltaic cell with a solar thermal collector, which captures and removes waste heat from the PV module. The capture of both electricity and heat allow these devices to be more overall energy efficient than solar PV or solar thermal alone.

IP65..Ingress Protection Rating; 6 for dust tight; 5 for water tight to standard water jets

Inverter..An inverter is an electrical power converter that changes direct current (DC) to alternating current (AC).

Isolator..A disconnector, disconnect switch or isolator switch is used to ensure that an electrical circuit is completely de-energised for service or maintenance.

kWh ....Kilowatt hour; the standard unit of measurement for electrical energy consumption (often known as a unit)

kWp ....Kilowatt peak; in order to rate and compare solar panels the concept of nominal power is used. The nominal power is measured in the lab under very specific conditions, as specified in international norms. In the panel datasheets these conditions are usually referred to as STC (standard test conditions). With the STC fixed the load of the panels is varied and the maximum generated power is recorded. This is the nominal power. It is measured in watt peak (unit Wp). The 'peak' is meant to emphasize that this is the power generated under optimal load condition, i.e. it is the 'peak' power. Standard conditions in the lab are hardly ever realistic in real life, and the load conditions are also not always perfect. But the nominal power rating is useful to compare different panels and allows the introduction of the standardized price per kilowatt peak (kWp). 1000 Wp = 1 kWp, 1000 kWp = 1 MWp etc.

LEC..Levy Exemption Certificate; electricity produced from designated renewable sources is exempt from the Climate Change Levy and is entitled to Levy Exemption Certificates (LECs) which can be bundled with the power when sold to a supplier. The payment received will be dictated by the Power Purchase Agreement. More information here http://www.tetaproject.co.uk/en/photovoltaics/climate-change-levy.html

MCS..Microgeneration Certification Scheme

Mean power load ....The average power load over a specific time period.

Module..A photovoltaic module is a packaged, connected assembly of solar cells.

Monocrystalline silicon ....Silicon in which the crystal lattice of the entire solid is continuous; unbroken (with no grain boundaries) to its edges.

MPRN..Meter Point Reference Number; the identifying number used by electricity companies for individual electricity meters.

Net present value ....tells you what an investment is worth to you today.

NIE ....Northern Ireland Electricity Limited owns and manages the electricity transmission and distribution assets in Northern Ireland; it is owned by the Electricity Supply Board in Ireland.

NIRO...Northern Ireland Renewable Obligation also known as RONI (see RO)

NIROC...Northern Ireland Renewable Obligation Certificate (see ROC)

OFGEM ....Office of Gas & Electricity Markets is the government regulator for the electricity and downstream natural gas markets in the UK.

Parallel Generator Agreement ..Agreement signed with NIE governing the terms of connection of a generator.

Power Purchase Agreement.....Agreement signed with a licensed energy supplier for purchasing generated electricity.

Pitch ....Tilt or slope of roof; measured in degrees from horizontal.

Polycrystalline silicon ....Polycrystalline silicon is a material consisting of multiple small silicon crystals. Polycrystalline cells can be recognised by a visible grain, a 'metal flake effect'.

Power NI ....One of the electricity supply companies in Northern Ireland, part of the Viridian Group, formerly part of NIE.

PV ....Photovoltaic

REAL Assurance Scheme..........Renewable Energy Assurance Ltd carries out a range of certification and consumer protection activities all of which promote sustainable energy.

Rent a Roof Scheme...................You lease your roof to the installing company which pays you by giving you the generated electricity.

RO...Renewables Obligation; the main support system for renewable generation in the UK.

ROC ....Renewable Obligation Certificate; a green certificate issued to an accredited generator for eligible renewable electricity generated within the UK and supplied to customers by a licensed electricity supplier.

SBEM ....Simplified Building Energy Model; to demonstrate compliance with UK Building Regulations

SEM ....Single Electricity Market; the marketplace for electricity in the island of Ireland.

Sensitivity analysis.....................Allows you to perform 'what if' scenarios on your financial predictions.

Simple pay back.........................The period of time taken to recover your costs on an investment.

Solar irradiance ....Irradiance is the power of electromagnetic radiation per unit area incident on a surface.

Spatial NI ....Spatial NI™ is the Northern Ireland Portal for Geographic Information.

Specific yield...............................kWh/kWp/a; the predicted generation in kilowatt hours per kilowatt peak per year.

Sun chart ....A sun chart is a graph of the ecliptic of the Sun through the sky throughout the year at a particular latitude.

Total return ....The percentage gain or loss on an investment over the time it is held.

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i kWp –kilowatt peak - kilowatt peak stands for peak power. This value specifies the output power achieved by a solar module under full solar radiation (under set Standard Test Conditions). Solar radiation of 1,000 watts per square meter is used to define standard conditions. Peak power is also referred to as “nominal power” by most manufacturers. Since it is based on measurements under optimum conditions, the peak power is not the same as the power under actual radiation conditions. In practice, this will be approximately 15-20% lower due to the considerable heating of the solar cells.

ii http://en.wikipedia.org/wiki/Low_Carbon_Building_Programme

iii MWp – megawatt peak – 1 megawatt = 1000 kilowatts

iv http://www.nie.co.uk/Connections/Generation-connections

v Price prior to Oct 2013

vi www.spatialni.gov.uk/geoportal/catalog/main/home.page

vii http://solardat.uoregon.edu/SunChartProgram.html

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ix http://mkchariths.webs.com/BS-6399-2.pdf Para 2.5

x http://www.bolton.gov.uk/sites/DocumentCentre/Documents/LABC%20Solar%20panel.pdf

xi http://www.microgenerationcertification.org/images/PV%20Book%20ELECTRONIC.pdf

xii http://www.solmetric.com/solmetricipv.html

xiii See HSG33 and HSG150

xiv http://www.hse.gov.uk/construction/cdm.htm

xv ISBN 978-0-9574827-0-8– Hard Copy / ISBN 978-0-9574827-1-5– Electronic PDF

xvi http://www.diykyoto.com/uk/aboutus/wattson-solar-plus

xvii http://www.microgenerationcertification.org/mcs-standards/installer-standards

xviii http://re.jrc.ec.europa.eu/pvgis/index.htm

xix http://www.solardesign.co.uk/pv.php

xx Kilowatt hours per kilowatt peak per annum

xxi Note that you will save VAT and any CCL charges on replaced electricity.

xxii A half hourly meter (HHM) registers how much electricity is used in a building for every half hour of every day. They typically have a fixed or mobile phone connection to provide this data to energy suppliers automatically each month, rather than be manually read. This helps energy suppliers issue accurate bills and show building occupiers how they use energy throughout each day.
See http://www.edfenergy.com/products-services/large-business/PDF/MBC-FS-HHM-002-1009.pdf

xxiii Power consumption is measured in kWh, power load is measured in kW. Dividing consumption by hours gives power.

xxiv http://www.nie.co.uk/Connections/Generation-connections/Small-scale-generation/11kV-Network-Heat-Map

xxv Single Electricity Market (See Glossary)

xxvi The Renewables Obligation (Northern Ireland) Order 2009

xxvii http://www.cse.org.uk/thesource/download/solar-pv-checklist-questions-to-ask-installers-85

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xxxii http://www.portmanassetfinance.co.uk

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xxxv http://www.recc.org.uk/

xxxvi http://www.detini.gov.uk/existing_and_confirmed_roc_per_mwh_levels_from_1_may_2013.pdf

xxxvii 2013 rate set each October

xxxviii Levy Exemption Certificate (See Glossary)

xxxix http://www.carbontrust.com/media/18223/ctl153_conversion_factors.pdf

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