CIC Start Online – Academic Feasibility Study
Scottish Energy Centre (HEI)
&
Port of Leith Housing Association (SME)

SOLAR PV FEASIBILITY STUDY FOR HOMES IN THE CITY OF EDINBURGH
1.0 PARTNERS DETAILS

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Section 8.0 – Jon Stinson  
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1.0 INTRODUCTION

The Scottish Energy Centre as part of the Institute for Sustainable Construction and Edinburgh Napier University was selected by CIC Start Online on behalf Port of Leith Housing Association (POLHA) to examine the potential for using solar photovoltaic (PV) technology in rented accommodation located in Edinburgh.

Port of Leith Housing Association is keen to address energy conservation issues across its housing stock. Since its inception in 1975, Port of Leith has been redeveloping older tenement properties in Leith as well as building a range of new properties in the wider Leith area. PoLHA has therefore been at the heart of the redevelopment of Leith, with new house building, property refurbishment and community regeneration being paramount amongst its activities. Energy conservation is already being partly addressed by complying with the 2015 Scottish Housing Quality Standards (SHQS) and by undertaking energy saving schemes throughout some selected properties. However with increasing requirements for reductions in carbon emissions, and increasing levels of fuel poverty among its tenants, energy efficiency and the use of renewable energy technologies remain high on the PoLHA agenda.

As energy conservation is tackled, there is also the concern of addressing appropriate methods of energy supply to the housing stock. As buildings account for nearly half of the country’s carbon dioxide emissions, the Scottish Government has set a number of targets to reduce carbon emissions. The Climate Change (Scotland) Act (2009) has put in place a legislative framework to pursue a reduction in emissions associated with the unsustainable use of fossil fuels and placed duties on public bodies. The Scottish Government’s commitment to increasing the amount of electricity and heat generated from renewable sources is a vital part of the response to climate change. The headline targets to generate the equivalent of 100% of Scotland’s gross annual electricity consumption and the equivalent of 11% of Scotland’s heat demand met from renewable sources by 2020 have spatial planning implications that need to be addressed in development plans. [1]

It is for this reason that PoLHA is concerned for the future regarding the source and use of energy. Dependency on global energy supply is a risk; both to the origin of the energy and its future availability. The global issue of finite energy sources will soon heavily impact upon the housing sector; therefore, it is a wise decision to investigate alternative methods of clean and cheap energy generation, in a bid to secure an independent energy supply for domestic dwellings.

1.1 FEASIBILITY STUDY BRIEF

PoLHA wished to undertake a feasibility study to examine the possibility of installing solar PVs to a number of properties within their housing stock located in the Leith area of the City of Edinburgh. Benefits include reducing electricity costs for the tenants; thus tackling fuel poverty, whilst at the same time reducing the carbon dioxide emissions. It is proposed that this study will be made available to other social rented landlords within Scotland and this would assist them in the understanding, application and development of similar PV systems within their own rented stock.

The study considered:
- Location and type(s) of PV panels to maximise solar gain, including output and returns
- Benefits of Feed-in Tariff in relation to provision of solar PVs
- Restrictions on PV placement on buildings in conservation area
- Changes to the government’s Feed-in Tariff scheme, and introduced stipulations
- Links with capital cost schemes like Rent a Roof

1.2 AIM & OBJECTIVES

The aim of the feasibility study was to highlight the technical and economic viability of using of solar photovoltaic panels for the generation of electricity within a range of preselected properties. It also focused on reducing fuel poverty by introducing effective, cheap and accessible means of supplying electrical energy to the homes. Another key aim was to indicate the carbon reduction against the investment over a longer period of time.
The following objectives were identified for the feasibility study:

a) Understand and review how solar PV panels operate and how to obtain optimum efficiency.

b) Discuss and evaluate the technical constraints related to what type of PV panel is optimum for the selected buildings and how that influences efficiencies and production.

c) Identify and explain the links between technical and energy suppliers sizing constraints.

d) Explore the role of the Feed-in Tariff and selling back to grid.

e) Understand the issues surrounding the economical payback of all equipment coupled with the sizing of equipment.

f) Articulate the role of the location and orientation of the properties.

g) Use case study examples to demonstrate “best practice” examples of renewable energy usage and application.

h) Explore the advantages and disadvantages of “Rent a Roof” schemes.

1.3 BACKGROUND

The Scottish Government draft electricity policy statement 2010 set out the latest position on Scotland’s future electricity mix including an update on the Scottish approach to energy efficiency and microgeneration as developed in the Energy Efficiency Action Plan. The Energy Efficiency Action Plan reaffirmed the Scottish Government’s ambitious energy efficiency and microgeneration agenda for Scotland and set out our wide-ranging programme of activity on behaviour change, household, business and public sector energy efficiency, infrastructure, skills, and transport. This framework furthers the government’s climate change, economic and social ambitions. It will drive the cost-effective action required if Scotland is to meet its challenging statutory emissions reduction targets of at least 80% by 2050 and 42% by 2020, as set out in the Climate Change (Scotland) Act 2009 and introduces a headline target to reduce Scottish final energy consumption by 12% by 2020, with an indication of how this will be monitored [2]

This feasibility study is set out to assist PoLHA to select the best properties suited to the retrofit of photovoltaic panels, in a bid to supply as many properties as feasible with cleaner cheaper electricity. With this technology in place, it is also of interest for PoLHA to take advantage of the Feed-In Tariff (FIT) scheme as a means of investment recovery and improved payback of such investment in solar PV. This document demonstrates how the investment can be paid back, allowing PoLHA to determine whether it is a viable and worthwhile venture, highlighting investment versus return, and exploring the income through the potential of selling generated electricity back to the grid.

1.4 EXISTING HOUSING STOCK

PoLHA has a wide range of properties available for rent and also manages sheltered housing for the elderly. The housing stock is located mainly in the Leith area of the City of Edinburgh. The study analyses properties located around Leith, the majority in the Leith Walk area, where a varied housing stock is located with different construction types, ages, and conservation constraints. Eight properties were analysed in this study, which include 13 PV installations. The majority of the selected dwellings will utilise such electricity in their communal areas, with the potential to implement it into individual flats. The selected properties are either sheltered accommodation apartments or what is called “flatted stairs” which correspond to a block of flats with access to the same communal areas. The selected properties range from buildings constructed in the 1980s to more recent properties built in the early 2000s.

1.5 METHODOLOGY

This study addressed the objectives identified above by conducting initial location surveys of preselected properties already identified by the PoLHA. This in-turn led to a further filtering study on the typology of the dwellings and the similarities that the buildings have. To avoid repeating information and specification, the selected eight properties were examined for their optimum roof shape and orientation. With these eight properties selected, the study then proceeded to conduct calculations and guidelines for that given roof type and orientation. The feasibility study presented economic and technical results that have been calculated with the assistance of a digital PV design and modelling software called PVSyst. With the aid of this software, each individual building parameter can be modelling and different PV systems can be simulated to shortlist the best performing PV system. Key building parameters integral to the modelling procedure include:
- Tilt of pitched roof (if flat roof an ideal & optimum tilt can be suggested)
- Orientation of roof (southern orientations)
- The amount of power required, in order to size the system
- Type of modules specified – monocrystalline or polycrystalline (see section 3.0)

In order to conduct the report and disseminate the results obtained by the software; it is essential that the following information is obtained:
- The initial electricity demand of property/block (communal or of the dwelling)
- Buildings location in relation to conservation areas
- Cost of the panels and equipment
- Funding mechanisms – government or other
- Cost of the price per kWh by the energy providers

The above provided the tools to conduct an economic feasibility framework which would determine whether the installation was feasible both technically and economically.

1.6 ENERGY EFFICIENCY

It is a key recommendation that the buildings seeking the addition of PV equipment undergo some form of thermal upgrading, whether that be in the form of a full refurbishment or intermediate steps to improve the thermal performance of the properties, for example, draught proofing, loft insulation, and/or wall insulation, use of double glazed or better windows with insulated frames, etc. These steps should be undertaken to complement any installation of renewable energy equipment. This is required to reduce a buildings energy consumption which, therefore, assisting the renewable microgeneration and depending less upon grid electricity and increasing utility bills. By making sure the property is thermally responsive, the use of alternative energy sources can be utilised as efficiently as possible.

Stipulations introduced by the government in relation to the change in the feed it tariff scheme, now require a building to have an EPC rating of D or above as a proviso to being awarded the respective generation tariff applicable to the size of PV equipment designed for the property, this is further discussed in Section 4.2.
2.0 PV BASICS

2.1 WHAT ARE PHOTOVOLTAICS?
Photovoltaic (PV) systems convert energy from the sun into electricity through semi-conductor cells. PVs supply electricity to the buildings they are attached to or to any other load connected to the electricity grid. Electricity is usually fed into the grid when the generated power exceeds the local need. PV systems can be off grid but it is unlikely any systems installed in the selected properties would be of this type. More electricity is produced with more sunlight, but energy can still be produced in overcast or cloudy conditions, so PVs can be used successfully in all parts of the UK, including the Highlands of Scotland, where the average annual sum of global irradiation per square metre received on a horizontal plane is 2.3 kWh/m². Photovoltaic panels can be fitted to existing buildings, designed into new buildings or attached to individual items such as street lights, parking meters or the sides of bridges.

2.2 BENEFITS OF PHOTOVOLTAICS
Incorporating photovoltaics into a roof can enable the building envelope to generate a percentage of its electricity for free, without the emission of greenhouse gases. These are clearly two important benefits, but as a technology it has a number of others [4]:
- No moving parts and therefore requires little maintenance
- No emissions in use
- Easy to install as modular and light
- Technically reliable – they are generally guaranteed to last over 20 years but are expected to last longer.
- Avoidance of climate change levy for non-domestic buildings
- Helping to meet national, regional or even local renewable energy and carbon dioxide emission targets
- PV produces electricity at point of need so energy is not lost moving it from one place to another
- One of the few renewable technologies that can be used very successfully in urban areas
- Architectural integration – PVs can be added almost invisibly to buildings, can be used as a design element or can lead the architectural concept of a building
- Marketing impact – a clear statement about renewable energy

There are still disadvantages with PVs – the major one being high cost. They are also still a relatively new technology so that there are not many architects, engineers, electricians or roofers with much experience of them; however, this is set to change as the government financing incentives become increasingly prevalent.

2.3 TYPES OF PHOTOVOLTAICS
PV cells come in a number of types with varying operating efficiencies in differing conditions with different costs attached:

<table>
<thead>
<tr>
<th>Type</th>
<th>Efficiency</th>
<th>Cost Comparison</th>
<th>m² per 1kWp</th>
<th>Other info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocrystalline silicon</td>
<td>15%</td>
<td>Expensive due to the manufacturing process. A pure single crystal of silicon is drawn from molten silicon and is then sawn into wafers</td>
<td>8 m²</td>
<td>Can only be manufactured in batches so this technology is not ideally suited to mass production</td>
</tr>
<tr>
<td>Polycrystalline silicon</td>
<td>8-12%</td>
<td>Cheaper than monocrystalline to manufacture as molten silicon is cast into blocks and then sawn into wafers</td>
<td>10 m²</td>
<td>Not well suited to mass production.</td>
</tr>
<tr>
<td>Amorphous silicon</td>
<td>4-6%</td>
<td>Cheap to manufacture as low temperatures are required and expensive sawing isn’t needed</td>
<td>20 m²</td>
<td>Use very thin layers of material so is referred to as thin-film and can be deposited onto a backing material such as glass or plastic (which can be flexible)</td>
</tr>
<tr>
<td>Cadmium telluride and Copper indium diselenide</td>
<td>7-9%</td>
<td>More expensive than amorphous silicon due to the low volume of production and the expense of the raw materials.</td>
<td></td>
<td>Both of these materials can be deposited as thin layers</td>
</tr>
</tbody>
</table>

Table 01 Efficiency of solar panels depending on their type [3]

*A kWp (kilo Watt peak) is the standard unit of measurement for PV systems. It refers to the peak power that the system can generate.
PV modules come in a wide array of configurations and can be fitted onto the roofs of buildings, onto facades, integrated into different building components and fitted to existing buildings. They are particularly suited to buildings that use electricity during the day – offices, retail and schools. The simplest option is to fit a modular panel to a pitched roof that has an optimum tilt suitable for efficient energy production, the panels can be integrated into the roof structure as slates or shingles, or bolted in modules to the top. The alternative is in a flat roof where a framework is installed to obtain the optimum tilt. These options can readily be retrofitted to existing buildings. PV panels can also be located and fitted onto facades vertically and also onto louvers which are sometimes very favourable in tracking the best angle for increased electricity production in accordance with the time of the day and the sun’s tilt.

2.4 DC CONNECTING CABLES
When solar modules are connected and working, direct currents of several hundred volts can be generated. For this reason, when DC currents exceed a protective low voltage of 120V, touch-proof wiring protected against short circuiting and accidental earthing must be employed. For outdoor PV installations, it is also very important that the materials used have high UV, ozone and temperature resistance. Accordingly, special solar cables with double insulation and excellent temperature/UV resistance are used for PV systems.

2.5 INVERTERS
Inverters convert the direct current (DC) created by the solar modules into alternating current (AC) suitable for the grid. At the same time, they monitor and regulate the feed of current into the grid, automatically disconnecting the PV generator from the grid in the event of a fault or grid failure.

3.0 SITE CONSTRAINTS
PV placement and siting decisions are fundamental to the design of PV systems. The most appropriate location for the optimum operation of the system is essential for the system to obtain as much sunlight as possible in order generate predicted energy output, making the investment worthwhile and leading to a shorter payback period. Solar panels can be installed in all orientations but some will produce low quantities of electricity while others, because of their orientation and tilt, can take advantage fully of the solar radiation.

In the northern hemisphere PVs should ideally face between Southeast and Southwest, at an azimuth (orientation) of about 30-40 degrees. Most systems in Britain operate more efficiently at these tilt angles and in Scotland the average efficient tilt is plus or minus 2 degrees of 40 degrees, however high levels of solar radiation is still achieved on tilts of 30 degrees, so no additional framing is required to increase a system from an existing 30 degree pitched roof. Systems should be in locations that will be un-shaded at all times of day. Gable roofs, chimneys, cables, TV aerials, trees and other buildings in the vicinity are identified as potential shading hazards. After the installation of the PV equipment, it is prudent to conduct periodic surveys of nearby trees, as the foliage that may not have been an initial issue during the design and implementation of the PV system, over time, may begin to impact on the PV system due to shading. Similarly, future extensions to the building or neighbouring buildings close to the PV system may negatively impact on the system’s annual energy production, reducing the system’s income potential. Figure 01 is an example of shading on a PV array.

It is often the case that insignificant elements like TV aerials, satellite equipment or cabling hanging above the modules are overlooked; however, due to the electrical characteristics of PV modules, this can have a very large impact on the performance of the system. Shade reduces the output of the shaded cells; the shaded cells then have an increased resistance to the flow of electric current which reduces the flow of electric current through all the cells joined to that cell.

Maintenance of such panels is essential; cleaning is needed if the area is known for a bird population (e.g. seagulls), which may need to be discouraged from perching near the systems. A maintenance regime should be adopted in which cleaning of panels is undertaken; as this can reduce their efficiency in the long term.

PVs need to be ventilated (underneath the modules) so that they don’t heat up – their efficiency decreases as the temperature rises. Suitable ventilation is easier to ensure for bolt-on systems on to roofs as they can overheat without proper air circulation.
The design of racks and structural elements bolted onto the roof should take this into account. This feasibility study has indicated that modules are to be attached to existing dwellings; therefore consideration should take place of the loading capabilities needed for the structure. It is recommended that a structural survey and detailed account of the considerable weights that will be imposed to the roof should be undertaken while also making sure fixings are securely and professionally installed.

Care must be taken if the systems are to be fitted to social housing properties with pre-payment meters as some meters do not allow the export of electricity and can be damaged by attempted export. It is also important to be aware of the current building’s electrical system type and whether it’s a single phase or 3 phase connection. The phase type will determine the size, configuration, wiring and number of inverters required to for the PV system, this will impact on the cost of the system.

Figure 01: Poor location design for PV installation – Source: EST, UK2010

3.1 PLANNING CONSTRAINTS IN CITY OF EDINBURGH

Further to the optimum site selection, a large majority of PoLHA properties fall within the Leith conservation area, as identified in Figure 02. The requirements and constraints of the City of Edinburgh planning office need to be considered and adhered to. This provides further challenges when selecting ideal roof location and siting parameters for the addition of solar PV equipment for those properties. The Town and Country Planning (General Permitted Development) (Scotland) Amendment Order 2011 came into force on 21st November 2011. The introduction of the order saw the removal of Part 1A (installation of domestic microgeneration equipment) of Schedule 1 classes 6A (solar PV equipment) as set out in earlier Town and Country Planning (General Permitted Development) (Domestic Microgeneration) (Scotland) Amendment Order 2009.

Figure 02: Leith conservation area, City of Edinburgh
As a result, the planning procedure surrounding the addition of PV equipment on to existing properties, now falls within “Class 2B.—(1) Any improvement, addition or other alteration to the external appearance of a dwellinghouse that is not an enlargement”. Under this class, the addition of PV equipment, not in a conservation area will fall under the “1 metre from face of building” rule, wherein, the addition of PV equipment is permitted without the need for planning permission, if it does not protrude more than 1 metre from the outer surface of an external wall, roof plane, roof ridge or chimney of the building. Unless otherwise stated, all of the PV panels referred to throughout Section 6.0 of this report will not have a thickness of more than 1 metre.

### 3.2 OUTWITH CONSERVATION AREAS

Properties that are not in the conservation area are deemed as permitted development under Class 2B (2)(a). Four of the properties to be analysed in Section 6.0 have been identified as being outwith the Leith conservation area, namely the properties at:

- Restalrig Circus
- Albert Street
- Academy Park
- Lorne Street

The PV system designed for these properties will be positioned on the face of the building that has a tilt between 30 and 50 degrees, facing between Southeast and Southwest, and not afflicted by shading projected by neighbouring structures or foliage.

### 3.3 WITHIN CONSERVATION AREAS

With the newly introduced 2011 amendment, properties that fall within conservation area are no longer part of the permitted development as covered in Class 6A(5) of the 2009 amendment, PV installations in these areas are not permitted under Class 2B, and will require full planning permission. As a result, a full planning application, including plans and relevant accompanying documentation will need to be submitted for planning approval.

Four properties analysed in Section 6.0 are within the Leith conservation area, namely:

- Ferry Road
- Sandport Way
- Jameson Place
- Constitution Street

For the purpose of this document, the properties listed above will be analysed, and the PV systems designed, in accordance with Schedule 1 classes 6A(5) (solar PV equipment within a conservation area) as set out in the earlier Town and Country Planning (General Permitted Development) (Domestic Microgeneration) (Scotland) Amendment Order 2009. Although this order has been superseded, it will provide the basis by which the location of the PV array may satisfy the planner’s requirements. In this respect, the placement of PV arrays on the four listed properties in the conservation area will be located away from the principal elevation of the building and positioned so as not to be visible from street level.

Note: the information presented in Section 3.1 to 3.3 is indicative only, and full consultation with the local planning officer is advised for each property at time of project realisation. Certificates of Lawfulness are a way of deciding whether the addition of the PV equipment, not in a conservation area and within the 1 metre rule, is legal or not.

### 4.0 FEED-IN TARIFF CONSTRAINTS

In order to make an investment into solar photovoltaic panels worthwhile with lower paybacks it is advisable to look into what is known as the Feed-in Tariff, often referred to as ‘FiT’. In April 2010 the UK solar PV Feed-in Tariff, also known as the ‘Clean Energy Cashback Scheme’, came into force. The solar PV Feed-in Tariff (FiT) is a government promoted incentive administered and regulated by OFGEM. The Feed-in Tariff obliges the traditional energy companies (known in this context as FiT Licensees) to pay the owner of a solar PV system above-market rates for the clean energy that they generate and also guarantees an additional price (per kWh) for the energy that they sell/export back to the grid.
The solar PV Feed-in Tariff has been designed to recognise the financial commitment of the solar PV system owner through a guaranteed repayment on their investment; in most cases a competitive return over and above what the system costs to install and in recognition of the contribution made to lowering the country's dependence on imported fossil fuels and lowering overall carbon dioxide emissions. The solar PV Feed-in Tariff is available for everyone including homeowners, businesses, schools and land owners. Income from the Feed-in Tariff is not subject to tax for homeowners.

4.1 GENERAL ASPECTS

Essentially the FiT scheme comprises two tariffs:

- The generation tariff
- The export tariff

The solar PV generation tariff guarantees a fixed payment (usually paid quarterly) based on the size of solar PV system that is installed and the amount of power (measured in kWh) that the solar PV system is capable of generating. Payments are guaranteed for 25 years and payment rates are index linked to inflation (using the Retail Price Index). More recently, the FiT incentives have been the focus of wide spread media and industry controversy, in short, the DECC issued reduced FiT rates, with the lower rates payable for systems installed after the end of March 2012. As confirmed by the DECC in the Feed-in Tariffs Scheme: Government Response to Consultation on Comprehensive Review Phase 1 – Tariffs for solar PV, published in 09-02-2012, changes will be made to the previously published generation tariff levels, with the new tariff, applicable for all installations from the 1st April 2012. Payment rates are fixed, based on the installation date. The new rates, applicable to the PV systems in this report, are outlined in the Table 02.

<table>
<thead>
<tr>
<th>Band (kW)</th>
<th>New generation tariff from 1 April 2012 (p/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 4kW (new build)</td>
<td>21.0</td>
</tr>
<tr>
<td>Up to 4kW (retrofit)*</td>
<td>21.0</td>
</tr>
<tr>
<td>&gt;4-10kW</td>
<td>16.8</td>
</tr>
<tr>
<td>&gt;10-50kW</td>
<td>15.2</td>
</tr>
</tbody>
</table>

* A retrofit installation is defined as any installation fitted to or wired to an existing building.

The solar PV export tariff applies to the proportion of clean energy that is exported (i.e. sold via the grid for others to use) and is set at a purchase price of 3.1pence per kWh. The export rate is guaranteed for 25 years and also index linked to the Retail Price Index (RPI). The export tariff is not applicable for off-grid PV systems. The scheme covers electricity-generating technologies, up to an installation size of 5 Mega Watts and the tariff can be applied to any type of solar PV system, including off-grid PV systems (the generation tariff) and Building Integrated PV (BIPV) systems, provided that both the solar equipment and the solar installer have been inspected and accredited to UK Microgeneration Certification Scheme (MCS) standards.

One of the main debates under the FiT constraints is what tariff to use. It is evident that the higher the FIT payment, the shorter the payback period will be. It is therefore suggested that an installation is made up of equal-to or less than 4kWp systems under the retrofit type of installation, as these will receive the highest tariff of 21.0p/kWh. If the installation is above this capacity but less than 10kWp system a 16.8p/kWh can be obtained. For systems above 10kWp the tariff begins to reduce and becomes less attractive but nevertheless can still provide a reasonable rate of return. The size of system designed for a building is also closely related to the number of panels able to be placed on the roof. The key objective is to design a PV system to generate as much as possible of the building’s electricity requirement, reducing the owner or occupier’s dependency on grid electricity and, as a consequence, their utility bills.
4.2 INTRODUCED ENERGY EFFICIENCY SECTION TO FIT SCHEME

The document ‘Feed-in Tariffs Scheme: Government Response to Consultation on Comprehensive Review Phase 1 – Tariffs for Solar PV’, published by DECC on 9 February 2012, also introduced an energy efficiency requirement. To meet the requirement, the applicant will need to demonstrate that the building designated for the solar PV installation, meets a certain level of energy efficiency. This is obtained through an assessment of the property carried out by a licensed Domestic Energy Assessor (DEA), after which an Energy Performance Certificate (EPC) is issued for the property, which must be rated level D or above. This condition applies to new solar PV installations, including extensions to existing solar PV installations, with an eligibility date on or after 1st April 2012.

The valid EPC accompanies the FIT application, which will then need to be verified as part of the FiTs accreditation process. If the FIT generator is not able to demonstrate this, then the installation will be eligible for a lower tariff of just 9p/kWh. The tariff available for those who do not meet the energy efficiency requirement will match the tariff for stand-alone* solar PV installations, and is the same across all levels of grid connected PV sizes, as shown in Table 03.

<table>
<thead>
<tr>
<th>Band</th>
<th>EPC rated below D (p/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4kW (new build)</td>
<td>9.0</td>
</tr>
<tr>
<td>4kW (retrofit)</td>
<td>9.0</td>
</tr>
<tr>
<td>&gt;4-10kW</td>
<td>9.0</td>
</tr>
<tr>
<td>&gt;10-50kW</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Table 03: FIT applicable to sites with a building EPC below D

*A stand alone system is defined as not attached to or wired to a building in order to provide electricity to that building, e.g. solar energy farms wired directly into the grid.

In some cases it may be possible to achieve level D by installing a PV solar equipment. However, if the subsequent EPC assessment shows that the newly installed solar PV equipment has not improved the rating of the building to a level of D or above, then the system will be unable to obtain the standard tariffs without undertaking further improvements to the energy performance of the property and obtaining another EPC assessment.

4.3 INTRODUCTION OF THE MULTI PV INSTALLATION TARIFF

The document ‘The Feed-in Tariffs Scheme: Government Response to Consultation on Comprehensive Review Phase 1 – Tariffs for solar PV’ referred to in 4.2 above, introduced multi-installation tariff rates as set out in Table 04. The rates are set at 80% of the standard tariff for individual installations where the FIT generator or nominated recipient owns or receives FiTs payments for one or more other solar PV installations, located on different sites. This is to avoid over-compensation for those in receipt of FiTs payments, given the economies of scale that arise from developing a large number of similar sites/aggregated projects compared to individual generators. The new multi-installation tariff rates are to be implemented into the new 1st April 2012 tariff. The rates will apply to any solar PV installation where the FIT generator or nominated recipient owns or receives FiTs payments from 25 or more other solar PV installations, located on different sites.

<table>
<thead>
<tr>
<th>Band</th>
<th>Multi-installation generation tariff (p/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4kW (new build)</td>
<td>16.8</td>
</tr>
<tr>
<td>4kW (retrofit)</td>
<td>16.8</td>
</tr>
<tr>
<td>&gt;4-10kW</td>
<td>13.4</td>
</tr>
<tr>
<td>&gt;10-50kW</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Table 04: FiT applicable to more than 25 installations

It is important to note that where a FiTs generator or nominated recipient is connected (within the meaning of section 1122 of the Corporation Tax Act 2010) to one or more other persons who are also FiT generators and/or nominated recipients, the solar PV installations associated with those other connected persons will also be considered in determining whether or not the threshold has been met and the multi-installation tariff rates are applicable [11].
4.4 APPLICATION TO FiTs
OFGEM administers a Feed-in Tariff register which holds the details of all registered generators. System registration is carried out via the FiT Licensees (the power companies). Once an eligible solar PV system has been installed the owner will be able to register it. An additional electricity meter to measure the electricity that the system is generating (known as a total generation meter), and also to measure how much is being fed back into the electricity grid (known as an export meter or a feed-in, feed-out meter), will be required. [5]

Meter readings must be returned to the suppliers, usually every quarter, which is also the period that payments are typically paid. Once the chosen installer has fitted the generating technology, it will be registered on the central FiT database and will then receive a certificate confirming FiT compliance. The owner then must inform the chosen energy supplier that the system is eligible to receive the FiT by providing the certificate. Once this is done, the supplier will then cross reference the installation with the central FiT database to verify its installation and that it has been installed by a registered MCS company. Payments will then be made by the energy supplier at intervals to be decided between the owner and the supplier which means the building user may be required to provide meter readings to the suppliers if requested.
5.0 GRID CONNECTION CONSTRAINTS

The UK power sector is a complicated and systematic industry that has recently been hit by the sudden need for grid connected renewable energy installations. This is due to the industry adapting to privatisation, changes in environmental awareness, technological developments and Government policy.

Traditionally, grid connections rely on a generating plant (fossil fuel) connected to an electric power transmission system followed by a distribution network to domestic, commercial and industrial energy users. That connection has now evolved into having a split generating source, it no longer relies purely on a generating plant but now also relies on renewable energy plants (High scale Wind, Hydro or other). Recently, more on-site electricity has been generated (CHP, PV, Wind) that can be re-distributed back to the grid, if surplus to the demand. This has been made possible with this evolved grid system that can receive generated electricity from other sources, rather than rely purely on generating plants and big renewable energy plants. These changes permit domestic and commercial on site generation more viable as there are occasions when excess of energy can be exported back to the grid contributing to the decarbonisation of the countries electrical grid system.

This feasibility study links the relationship between solar PV systems and the energy generated and the type of electrical phase connection the system will have. To simplify the connection it is suggested that the installation in a dwelling is done using a maximum of 3.65kW in single phase installation with a 16Amp system. This connection route and single phase installation does not require prior notification to the Distribution Network Operator (DNO). In order to connect and obtain grid connection benefits and tariffs both for generating and for exporting, a G83/1 application form is filled in and submitted to the DNO after installation.

When installing ‘multiple’ 3.65kW single phase systems in different building blocks, no prior notification before installation is required using the G83/1 guidelines if the system is ≤10.8kW. If this option is taken, it is recommended that installations have systems lower than 10kW to take advantage of the higher FiT’s; thus close to 10kW systems i.e. 9.8kW installations are most common.

If the installations are above 3.65kW/phase then a different route has to be taken. With systems up to 17kW for single phase, 35kW for dual phase and 50kW for three phases G59/2 application to the DNO have to be completed prior to any installation. This application can take up to 65 days and can cost between £300 & £800 per application, per dwelling. These costs can vary depending on the DNO. [7]
6.0 CASE STUDIES OF DWELLINGS

PoLHA provided a list of preselected properties (see Table 05), designated for the PV feasibility study. The locations of the eight properties in relation in Edinburgh City centre are marked in Figure 03. Figure 04 shows the location of each property in relation to each other and the surrounding Leith and Docks area.

<table>
<thead>
<tr>
<th>Reference on Map in Figure 03, and 04</th>
<th>Section number</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.1</td>
<td>Restalrig Circus</td>
</tr>
<tr>
<td></td>
<td>6.1.1</td>
<td>58, Restalrig Circus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 2-3 storey, pitched roof</td>
</tr>
<tr>
<td></td>
<td>6.1.2</td>
<td>58, Restalrig Circus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 2-3 storey, pitched roof</td>
</tr>
<tr>
<td>B</td>
<td>6.2</td>
<td>74 Ferry Road</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 3-4 storey, pitched roof</td>
</tr>
<tr>
<td>C</td>
<td>6.3</td>
<td>Sandport Way</td>
</tr>
<tr>
<td></td>
<td>6.3.1</td>
<td>Blocks 1, 3, 5, 9 and 11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 5 storey, low pitch curved roof</td>
</tr>
<tr>
<td>D</td>
<td>6.4</td>
<td>17 Albert Street</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 5 storey, pitched roof</td>
</tr>
<tr>
<td>E</td>
<td>6.5</td>
<td>23 Jameson Place</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 3 storey, pitched roof</td>
</tr>
<tr>
<td>F</td>
<td>6.6</td>
<td>3 Academy Park</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 4 storey, pitched roof</td>
</tr>
<tr>
<td>G</td>
<td>6.7</td>
<td>34 Lorne Street</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residential 4 storey, pitched roof</td>
</tr>
<tr>
<td>H</td>
<td>6.8</td>
<td>108 Constitution Street</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• New build, office block, low pitched roof</td>
</tr>
</tbody>
</table>

Table 05: List of analysed properties

Figure 03: City of Edinburgh with locations of selected case studies
COST ANALYSIS CONSIDERATIONS
The cost analysis of the solar PV systems in this report takes into consideration and evaluate the following information:

- Capital cost of materials
- Labour to install such panels
- VAT on labour & materials
- Yearly estimated maintenance fee
- Estimated inverter replacement (once every 20 years)
- Decrease in solar panel efficiency
- Feed in Tariff rate and its yearly increase in line with the Retail Price Index (RPI)
- Savings made on electricity bill, based upon electricity price per kWh and its estimated increase with inflation
- Electricity export at £0.31/kWh (if applicable)
- This study doesn’t explore the financial implications of securing loans for the capital cost of the equipment
6.1 RESTALRIG CIRCUS
The properties within Restalrig Circus do not fall within the Leith conservation area (see Figure 05).

![Figure 05: Restalrig Circus location in relation to the conservation area](image)

6.1.1 58 RESTALRIG CIRCUS
Overview
Designed in 1998, the property is part of several buildings added to the existing Restalrig Circus estate. 58 Restalrig Circus is built on a gradient site, providing the building with its distinctive stepped design. In turn, the building is divided into two main living blocks, a two storey block and a four storey block, centrally connected by a communal area. As a result, the building has three roof areas, all of which are within the preferred South to Southeast orientation, which would allow this property to benefit from the addition of a PV system. The areas of roof marked in Figures 06 and 07 represent the areas which have been analysed for the addition of a PV system.

![Figure 06: 58 Restalrig Circus aerial view](image)  ![Figure 07: 58 Restalrig Circus street view](image)

Orientation/azimuth: The appropriate roof for this study is indicated with red on Figure 06. Its orientation is 32 degrees facing Southeast.

Roof Pitch: The roof inclination is approximately 30 degrees from the horizontal.
Roof area: The total roof area is calculated at 288 m², and the portion of roof area facing South is approximately 150m². The middle roof covering the connecting communal stairwell measured at 30 m² has been excluded due to its size, existing aperture and over shading caused by the taller connecting building. The combined roof area is 120 m², split across the two larger roofs, providing an approximate 60 m² on the two storey dwelling and 60 m² on the four storey dwelling.

Shading: The four storey block of dwellings approximately 14.5 metres high has no surrounding shading that will imposing upon the PV layout. The second roof is 3 metres lower; this area is not impacted upon by any surrounding foliage or building shading, however, the stepped design of the three structure building results in a small portion of the lower roof being over shadowed on the Southeast orientation. To overcome this factor, the panel layout on the lower roof has been positioned to the further West side of the roof as illustrated in Figure 08.

Estimated energy consumption: The energy consumption for the electricity used in the communal areas of 58 Restalrig Circus has been calculated based upon the issued utility bills provided by PoLHA. Graph 01 has plotted the electricity consumed over a one year period. An expected consumption pattern is illustrated in Graph 01, with a peak in consumption over the darker winter periods, and consumption levels dropping off as artificial lighting is required less in the spring/summer period. Based upon the estimated meter readings from the utility bills, the annual electricity consumption has been calculated to be 8,300kWh. The total cost of the energy used during the same period including VAT, standings charges etc. was £980.

System options and selection: Multiple system options have been designed and simulated based upon the parameters of the building and roof structure of 58 Restalrig Circus, Table 06 lists three configurations of PV systems selected for their higher produced energy output. As illustrated in Figure 06, the roof area on 58 Restalrig Circus allows for uninterrupted placing of panels, which is demonstrated in Figure 08, with no dormer windows or other apertures/roof structures prohibiting the design layout of the panel. This resulted in the top three system options being similar. The main difference in the system options is the inverter size, power per module and the solar panel technology.

<table>
<thead>
<tr>
<th>Project - Building location</th>
<th>Usable roof area</th>
<th>Roof - Tilt/azimuth</th>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Phases</th>
<th>Number of modules</th>
<th>Power per module (Wp)</th>
<th>Total power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>58 Restalrig Circus</td>
<td>Area 1 - 60m², area 2 - 60m²</td>
<td>30' &amp; 32' South East</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>39</td>
<td>250</td>
<td>9.8</td>
<td>1</td>
<td>7.7</td>
<td>3</td>
<td>7613</td>
<td>781</td>
</tr>
<tr>
<td>2</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>42</td>
<td>235</td>
<td>9.9</td>
<td>1</td>
<td>9.0</td>
<td>3</td>
<td>8089</td>
<td>820</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Polycrystalline</td>
<td>Single</td>
<td>42</td>
<td>230</td>
<td>9.7</td>
<td>1</td>
<td>9.0</td>
<td>3</td>
<td>7496</td>
<td>776</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 06: System sizing using three module & inverter options – Property: 58Restalrig Circus
The selected system for further analysis was option 02, which is a 42 x 235Wp monocrystalline panel system with a total power output of 9.9kWp, producing an average annual estimated energy output of 8,089kWh. Referring back to the total annual electricity consumption for the communal areas in this property, it can be observed that there is an estimated usage of 8,300kWh. Once compared with option 02 and its output, the designed PV system has the potential to contribute 97 per cent of the buildings annual communal electricity demand, this indicates a saving of just over £950 per year. This figure increases as and when the grid electricity price increases.

![Figure 08: Proposed module set up on roof of 58 Restalrig Circus – numbers indicate the 3 different strings of panels.](image)

**Economic analysis**

Option 02 has an estimated cost of £30,000 to £31,000; this figure includes the total estimated cost for the technology, delivery, installation and other extras with VAT. Option 2 has a lower capital cost than option 1. Although option 2 requires more modules, the lower power of the modules reduces the cost per Watt peak and allows for higher annual energy produced. This makes the system in option 2 more financially attractive.

Further analysis on investment and payback is displayed in Graphs 02 and 03. It can be observed that the payback period is in year 12 - 13 in which the system is operating and obtaining the Feed in Tariff. The income generated from the Feed in Tariff accumulates to £54,200 over the 25 years. Savings on electricity bills at a rate of £0.10 per kWh, amounts to £33,600 over the 25 years. FiT increases with inflation and also the reduction in efficiency of the system during the 25 year period has been factored into the overall calculations, the final figure calculated for this system has been calculated to be £80,900 over the 25 year period. This figure takes into consideration any additional payments throughout the 25 year scheme, i.e. maintenance for cleaning the panels and inverter replacement once every 20 years.

Graph 02 charts the yearly payback over the 25 year FiT scheme. The income generated from the PV system will be repaying the initial capital cost of the system for the first 12 years. Over the 25 year analysed timeframe, the system will have saved 100 tonnes of carbon dioxide emissions being produced from grid electricity. Graph 03 shows the effect of the gradual reduction in efficiency of the system over the 25 years. The first years total electricity generation at 8,098kWh reducing to 7,170kWh in year 25. Similarly, the graph shows the carbon savings each year, over the 25 year period.
Graph 02 Cumulative financial balance of the investment

Graph 03 Yearly Electricity generated over CARBON DIOXIDE savings
6.1.2 56 RESTALRIG CIRCUS

Overview
56 Restalrig Circus is the second block of dwellings on Restalrig Circus to be analysed for PV application. This property comprises three building units with 12 rented flats built in 1998. Two of the three blocks within the building are four storeys tall with a third two storey building joined to the East block, forming a L shaped footprint, see Figure 09. The entire building is designed with a light coloured harling render on the exterior walls accompanied by darker brick which is also used in the construction of the boundary walls, with distinctive blue coated timber framed windows. The building is part of 10 additional buildings that have been added to the existing 25 properties at Restalrig Circus. The building faces into the nucleus of Restalrig Circus, overlooking the Prospect Bank Place allotments to the North. Figures 09, 10 and 11 have been marked to indicate the area of roof that will be analysed for the addition of a PV system.

Orientation/azimuth: The two four storey blocks are facing 5 degrees off the North South cardinal. Facing in a South-westerly direction, this falls within the desired design parameters for the optimum building orientation to maximise the solar collection of PV panels.

Roof pitch: The roof inclination is within the desired 30 degrees roof pitch, which will allow for maximum solar collection.

Roof area: Based upon ridge lines, the roofs can be divided into four areas. The portions of the roof facing close to due North, East and West have been excluded from the design analysis, these areas will be not be exposed to same level of sunlight as the more desirable South facing portion of the roof. The area marked up in Figure 09, represents the best location on 56 Restalrig Circus to locate PV panels. This area has been calculate to be 100 m$^2$, an existing aperture in the centre portion of the South facing roof further reduces the available area to 85 m$^2$, as shown in Figure 12.

Shading: Figure 10 and 11 demonstrate that the roof is located above any taller objects and elements that could overshadow the proposed modules. The pitched dormer type roofs atop the South facing gable ends could cast small shadows at various time in the morning and evening. Therefore as shown in Figure 12, the PV modules have been positioned to consider any overshadowing from these structures.
Estimated energy consumption:

Graph 04 has been generated based on 13 months of electricity bills issued by the utility company to the Port of Leith Housing Association. Many of the meter readings obtained from the billing information have been based upon estimates, however, this data still provides an indication of the electricity consumed within the communal area of 56 Restalrig Circus. The total electricity used over an annual cycle has been estimated to be 5,600kWh, with peaks in the winter and lower consumption levels in the spring/summer as expected. The consumption pattern at 56 Restalrig Circus is similar to that of 58 Restalrig Circus. Based upon the stated electricity tariff plus value added tax, the total cost of the electricity consumed of the 2010 -2011 period has been calculated at £710, this figure includes the additional standing or quarterly charges imposed by the utility company.

Graph 04: Electricity consumption for 56 Restalrig Circus 2010 – 11

System options and selection:

Table 07 lists the top three simulated systems modelled for the property, the highlighted option is the system selected as best fit option, based on energy generation and initial cost. The Monocrystalline 36 x 260Wp set of modules, along with a 9kW inverter, can produce around 7,500kWh of energy per year. This system was selected for its higher capacity and high yearly electrical output. Figure 12 illustrates the modelling design layout of PV panels on the portion of roof earlier identified in Figure 09, 10 and 11.

<table>
<thead>
<tr>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Number of modules</th>
<th>Power (Wp) per module</th>
<th>Total Power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monocrystalline</td>
<td>36</td>
<td>260</td>
<td>9.4</td>
<td>1</td>
<td>9.0</td>
<td>3</td>
<td>7524</td>
<td>804</td>
</tr>
<tr>
<td>2</td>
<td>Monocrystalline</td>
<td>36</td>
<td>255</td>
<td>9.2</td>
<td>1</td>
<td>9.0</td>
<td>3</td>
<td>7383</td>
<td>804</td>
</tr>
<tr>
<td>3</td>
<td>Monocrystalline</td>
<td>36</td>
<td>240</td>
<td>8.6</td>
<td>1</td>
<td>8.0</td>
<td>3</td>
<td>6913</td>
<td>800</td>
</tr>
</tbody>
</table>

Table 07 System sizing using three module & inverter options – Property: 56 Restalrig Circus
The PV design simulations suggest the configuration set out in Figure 12 to be the better performing system. Furthermore, the total generated energy can fulfil the calculated annual communal area electricity demand of 5,600kWh/year, therefore resulting in the potential to export 1,950 kWh (35%) back to the grid at the 3.1p export tariff.

**Economic analysis:**

Option 1 was closely priced to the other two options detailed in Table 07, by, the output of produced energy resulted in option 1 being the more financially attractive system, allowing for more energy to be exported and a higher rate of return on the export tariff.

The initial capital cost of the materials for the system in option 1, designed upon the parameters outlined throughout section 6.1.2, have been calculated to be circa £20,000. With the addition of labour, installation, delivery and charges including value added tax, the total cost for the system is calculated to be circa £33,000. Taking into consideration the Feed in Tariffs, the cost of saved electricity and the other cost for maintenance and inverter replacement, the estimated payback period for this installation would be between year 14 and 15 of the scheme as illustrated in Graph 05. This takes into consideration other payments incurred but a more detailed estimated capital cost should be made when contracting and obtaining quotes from MCS accredited installers.

Based on the post March 2012 Feed in Tariff of 16.8p/kWh for systems under 10kWp, the cost analysis of the PV design indicates that the system would raise approximately £50,400 in revenue, which could be used for panel replacement or fabric maintenance/improvements, if and when required. The estimated unused electricity (1,950kWh) exported back to the grid at 3.1pence per kWh would generate an additional income of £60.00 per year in the first years and increasing with the Retail Index Price increment to £91 in the final year of the FiT scheme, resulting in a total £1,900 over the 25 years. Furthermore, the savings made through the production of onsite electricity, and not paying utility company bills equates to a total circa £24,800 over the 25 years. Over the 25 year analysed period, the system will have saved 92 tonnes of carbon dioxide compared to using grid electricity.

Graph 06 shows how initial energy production estimated at 7,524kWh decreases to 6,672kWh after 25 years; a 11% decrease in panel efficiency which is also reflected in the carbon emission offsetting, moving from 3.92 tonnes saved on year one, down to 3.48 tonnes in year 25. A slightly larger power output system could have been designed for 56 Restalrig Circus, however, as the system size increases, the Feed in Tariff reduces the amount of financial incentive per kWh. Furthermore, with current grid connection application it is advisable to keep the system below a 10kW array. The designed PV array has the potential to generate a total of 177,000 kWh.
Cumulative financial balance (£)

Yearly Electricity generated over CO2 savings

Graph 05 Cumulative financial balance of the investment 56 Restalrig Circus

Graph 06 Yearly Electricity generated over carbon dioxide savings 56 Restalrig Circus
6.2 74 FERRY ROAD – SHELTERED HOUSING

Overview
The property on Ferry Road falls within the Leith conservation area, marked in Figure 13; as a result, planning permission will need to be sought for the addition of PV equipment. For the purposes of this document, the parameters discussed in Section 3.3, will be adopted in the design of PV array for this property. The area for the PV array will be located away from the principal elevation of the building and positioned so not to be visible from street level.

The property has two pitched roofs, with roof top access and walkway separating the two roof structures (as seen in Figure 14). The South elevation in Figure 15 shows the building’s stepped elevation, consisting of a three and four storey block. This elevation provides examples of the feature triangle bay windows that scale the full height of the four storey building. The building was constructed in 1989, the facade finished with a light sand coloured block, with dark brown timber framed windows, and dark brown coated steel balcony walkway over the front entrance which provided access on to Ferry Road. The roof is constructed of a timber structure, covered in slate tiles on the outward facing elevation, and cement tiles on the portion of the roof facing inward, onto the rooftop walkway. The property houses sheltered accommodation consisting of 35 self-contained one and two bedroom flats. It is managed by a concierge service, with a garden enclosed to the Northwest of the site. The energy harnessed from a designed PV system will be used to reduce dependence on the amount of grid electricity.

Figure 13: 74 Ferry Road location in conservation map

Figure 14: 74 Ferry Road aerial view

Orientation/ azimuth: The front elevation of the building, left of the main entrance is orientated 15 degrees Southeast. The PV placement area labelled PV01 in Figure 14 is also 15 degrees Southeast, the area marked PV02 is 60 degrees Southeast.

Roof Pitch: The roof covering the West wing of the building has been calculated and assumed to be at 30 degrees; however, more accurate measurements should be taken at time of project realisation.

Roof area: The roof has a service access point through a maintenance hatch located on the flat roof portion of the building atop the North wing. Based upon Planning order 2011, and design simulations, the portion of the roof marked in Figure 11 is the optimum area on the building by which to install a PV array, this area has been measured to be 45 m².

Shading: A field survey has revealed no nearby shading from other buildings or foliage that will currently or in the near future adversely affect the performance of proposed panels due to undesired shading. It will be subjected to shading cast from the roof on the elevation, this will only occur in early morning and late evenings. The PV system will be positioned to reduce the amount of shading, and this will reflect in the energy out of the design PV system.
Estimated energy consumption:
Graph 07 displays the electricity consumption for 74 Ferry road. The graph has been generated using the electricity bills from 2010 and 2011 provided by PoLHA. Although based on estimated meter readings, the data provides a good indication of the electricity consumption pattern over a 24month period. This data is important in the calculation to design the PV system for the building.

The results in Graph 07 present a typical consumption pattern for electrical energy (kWh) over the first three quarters, with an unexpected rise in consumption towards the end of the displayed period. Without the use of sub-metering, it is uncertain why there is a slight rise in electricity use over the summer period, this may be attributed to increased use of the elevator, and/or of the communal tea room, however this anomaly may also be attributed to the estimation procedure used by the utility company. The total annual consumption for the period August 2010 to August 2011 is 43,039kWh, with a cost of £4332, calculated from the electricity bills. Both this figure and the cost (£) information in Graph 07 are inclusive of VAT and standing charges.

System options and selection:
Based upon the data retrieved from the architectural drawings, and a building survey, several different PV systems were modelled and their performance simulated to define the most appropriate PV system. Table 08 lists three PV systems, selected for the amount of energy they produce each year. The key differences amongst the three, are the total power of the modules and the type of technology. Ultimately option number 2 was chosen as it was the system with the highest produced energy output (kWh/year). This system has a similar yet slightly higher cost to the other two options; however, the total generated energy can fulfil a higher portion of the energy demand for the building, (circa 3,100kWh/year of 43,000kWh/year).
Figure 16 indicates the proposed configuration of the panels according to the required number of strings and in line with the roof geometry and constraints. The panel layout considers the shadowing imposed by the nearby roof on the front elevation of the building.

Economic analysis:

The cost of the designed PV system based on option number 2 from Table 08 has been calculated to be circa £8,500. Including transportation, installation and associated labour plus VAT has been calculated at around £13,900. Based on the 21kWp Feed in Tariff, the system is designed to generate 655kWh in the first year while at the end of the scheme, with retail index price increase and the tariff increases, the system would be earning £1,560 in its last year of production. During the 25 year FiT scheme it is estimated that the system would generate just above £26,100. In addition to this, the system is designed to produce 3,122kWh/year, calculated as approximately 7 per cent of the building’s annual estimated electricity requirement. The system will therefore be saving £312 of the electricity bill in the first year, and £800 in year 25, totalling £13,000 over the 25 year period (this figure takes into consideration inflation in electricity tariffs, and degradation in panel efficiency). The system’s payback on the electricity bill is not restricted to the 25 year FiT scheme. The system will continue to save money on the electricity bill during the whole life of the system. The PV Simulation results show that 39 tonnes of carbon dioxide can be saved over the 25 year analysed period, in comparison to grid electricity.

Taking into consideration the Feed in Tariff incentive (21p for 4kWp systems post March 2012), the electricity savings and the other cost for maintenance and inverter replacement, the estimated payback period for this installation would be between year 13 and 14 of the scheme, as illustrated in Graph 08. This takes into consideration other payments incurred, but a more detailed estimated capital cost should be made when contracting and obtaining quotes from MCS accredited installers. Given the size of roof available and building orientation, this system provided the largest kWh/year output. Other systems were modelled and simulated to reduce the payback period; however, the price of the PV systems is closely linked to the power per module (Wp), which in turn influences the kWh/year output of the system. Therefore the lower the cost of the system impacts upon the total energy output, as the Feed in Tariff is paid on the amount of energy produced. The cheaper systems analysed had a similar investment cost yet increased the payback period to much later in the 25 year period.

Graph 09 shows how initial energy production estimated at 3,122kWh/year decreases down to 2,766kWh/year after 25 years. This 11% decrease in panel efficiency is also reflected in the carbon emission offset from 1.63 tonnes saved in year one down to 1.44 tonnes in year 25.
Graph 08 Cumulative financial balance of the investment

Graph 09 Yearly Electricity generated over carbon dioxide savings
6.3 SANDPORT WAY
The building at Sandport Way is within the City of Edinburgh Leith conservation area, as shown in Figure 17, and therefore, the PV array will be designed so to be placed in an area on the building that is not the principal elevation nor to be visible from street level. As the building has a flat roof, further design considerations will be undertaken to minimise the visual impact of the PV array on the building and to the surrounding area. To this end, the area for the PV array should be designed to be set back 1 metre from the edge of the roof, with the additional angling framework designed to prevent the PV array from protruding 1 metre above the plane of the roof.

Figure 17: Sandport Way location in conservation map

6.3.1 1, 3, 5, 9 and 11 SANDPORT WAY
Overview
1, 3, 5, 9 and 11 Sandport Way relate to five blocks of flats which are housed within the same building, (Figures 18, 19 and 20). The building is positioned at the corner of Sandport Way and Sandport Place, located close the Water of Leith, and situated in Leith’s Docklands. The building is a relatively new addition to the Dockland area, and is one of three new residential buildings constructed in 2003. The study for this location will look at splitting the roof into five areas, indicated in Figure 18 as PV01, PV02, PV03, PV04 and PV05. The investigation will focus on designing five PV arrays to generate electricity for the respective blocks, each of which has its own electricity meter. The PV cost analysis will comment on each of these as individual installations.

Figure 18: Sandport Way block 1, 3, 5, 9 and 11 aerial view
Orientation/ azimuth: The roof of the building curves from Southeast to Southwest,
- PV01 is 25 degrees facing Southwest,
- PV02 is 5 degrees Southeast,
- PV03 is 25 degrees Southeast,
- PV04 and PV05 have been calculated to be 40 degrees Southeast.

Roof Pitch: The inverted pitched roof of the building, as pictured in Figure 19, requires the PV array design to be positioned on the back portion of the roof. Furthermore, the roof is angled at a 10 degree runoff, towards the centre, this is not an optimum condition, and will require addition framing and PV angling support to increase the tilt to the desired 30 degree, as marked in Figure 19. (Figure 19 is not representative of the actual PV placement, it is indicative of the necessary angle increased required).

Roof area: For installation purposes, the five PV arrays have been grouped into three 32 m$^2$, and two 30.2 m$^2$ areas, totalling 156.4 m$^2$ across length of the roof, marked in Figure 18. The PV placement area designated as PV01 and PV02 are restricted by existing apertures, (roof lights/access hatches), reducing the number of panels allocated to those areas.

Shading: The roof is not subjected to shading from surrounding buildings or foliage. A portion of the building in the Northeast is taller than the main portion of the building, which will create small amount of shadowing, but not of significant length to influence the area PV04.

Estimated energy consumption:
The consumption of electricity in the common areas of four of the five blocks has been calculated from invoices issued to PoLHA from the utility company. The information obtained had been subject to utility company calculations, end of year adjustments and estimated meter readings, and as a result, the electricity consumption and cost per month had been even levelled out. This data provides no indication of consumption pattern over a calendar year. However, the more relevant data on annual energy consumption and associated costs provide the basis on which a PV system can be designed.

Table 09 provides a summary of the electricity and cost consumption for each of the communal areas within the five blocks. 1 Sandport Way has consumed significantly more than the other two blocks. This anomaly may be caused by the inaccuracy attributed to utility company calculating consumption from estimated meter readings, as large corrections in values are typically conducted at the end of each year by the utility company. Therefore, based on the information from the other three blocks, 10,000kWh/year is deemed high consumption value for the electrical needs for the communal area of just one block. Without accurate metering readings or data from sub-metering the PV systems will be designed to achieve as close to 4,000 kWh/year as reasonably practicable. No invoicing or consumption data was available for block 11; therefore, the figures displayed for Block 11 are an average of the blocks 3, 5 and 9.
**System options and selection:**

A wide variety of PV array systems have been simulated for each of the PV placement areas marked in Figure 18. Results from the digital modelling identified significant similarities in the system options for each of the PV placement areas. The available areas allocated to each of the PV arrays fall into two sizes, and the orientations of each area are similar. Therefore, so to prevent publishing repeated tables, Table 10 lists the top three options chosen for each of the two area sizes, to provide an indication of the different annual generation figures attributed to the sizes of systems. The highlighted systems are the preferred option based on the produced energy output of the systems and the capital cost.

Table 11 presents the selected systems for each of the PV placement areas, with the annual generation figure individually calculated to each of the different orientations. The difference in produced energy output across the five systems is a result of the different area sizes and orientations along the curved roof. The information displayed in the produced energy column of Table 11, is the figure used in the economic analysis for each of the blocks within Sandport Way.

### Table 10: System sizing using three module & inverter options for different area sizes - Sandport Way

<table>
<thead>
<tr>
<th>Project - Building location</th>
<th>Usable roof area</th>
<th>Roof - Tilt/azimuth</th>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Phases</th>
<th>Number of modules</th>
<th>Power per module (Wp)</th>
<th>Total power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV 12 Panel array options</td>
<td>30.2 m²</td>
<td>Based upon 30° &amp; 10° Southwest</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>12</td>
<td>255</td>
<td>3.1</td>
<td>1</td>
<td>3.0</td>
<td>1</td>
<td>2424</td>
<td>724</td>
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<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Polycrystalline</td>
<td>Single</td>
<td>12</td>
<td>240</td>
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<td>1</td>
<td>2.6</td>
<td>1</td>
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<td>771</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>12</td>
<td>250</td>
<td>3.0</td>
<td>1</td>
<td>2.6</td>
<td>1</td>
<td>2304</td>
<td>768</td>
</tr>
<tr>
<td>PV 14 panel array options</td>
<td>32 m²</td>
<td>Based upon 30° &amp; 30° Southeast</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>14</td>
<td>250</td>
<td>3.5</td>
<td>1</td>
<td>3.5</td>
<td>1</td>
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<td>780</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>14</td>
<td>255</td>
<td>3.6</td>
<td>1</td>
<td>3.5</td>
<td>1</td>
<td>2793</td>
<td>767</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>14</td>
<td>240</td>
<td>3.4</td>
<td>1</td>
<td>3.0</td>
<td>1</td>
<td>2651</td>
<td>789</td>
</tr>
</tbody>
</table>

### Table 11: System sizing for each PV placement area – Sandport Way

<table>
<thead>
<tr>
<th>Project - Building location</th>
<th>Usable roof area</th>
<th>Roof - Tilt/azimuth</th>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Phases</th>
<th>Number of modules</th>
<th>Power per module (Wp)</th>
<th>Total power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandport Way PV01</td>
<td>30.2 m²</td>
<td>30° &amp; 25° Southwest</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>12</td>
<td>255</td>
<td>3.1</td>
<td>1</td>
<td>3.0</td>
<td>1</td>
<td>2455</td>
<td>787</td>
</tr>
<tr>
<td>Sandport Way PV02</td>
<td>30.2 m²</td>
<td>30° &amp; 5° Southeast</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>12</td>
<td>255</td>
<td>3.1</td>
<td>1</td>
<td>3.0</td>
<td>1</td>
<td>2426</td>
<td>793</td>
</tr>
<tr>
<td>Sandport Way PV03</td>
<td>32 m²</td>
<td>30° &amp; 25° Southeast</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>14</td>
<td>250</td>
<td>3.5</td>
<td>1</td>
<td>3.5</td>
<td>1</td>
<td>2718</td>
<td>776</td>
</tr>
<tr>
<td>Sandport Way PV04</td>
<td>32 m²</td>
<td>30° &amp; 40° Southeast</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>14</td>
<td>250</td>
<td>3.5</td>
<td>1</td>
<td>3.5</td>
<td>1</td>
<td>2693</td>
<td>769</td>
</tr>
<tr>
<td>Sandport Way PV05</td>
<td>32 m²</td>
<td>30° &amp; 40° Southeast</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>14</td>
<td>250</td>
<td>3.5</td>
<td>1</td>
<td>3.5</td>
<td>1</td>
<td>2693</td>
<td>769</td>
</tr>
</tbody>
</table>

PV01 and PV02 are designed to occupy the same size of roof area, as illustrated in Figure 21. The location of existing roof apertures is the key component that has influenced the mounting arrangements in each of smaller areas. The mounting positions for PV03, PV04 and PV05 are not restricted by any existing roof structures, and their placement is represented in Figure 22.
Economic analysis:
The systems are designed to be below 4kWp, therefore the FiT used in the analysis for all five systems is the £0.21/kWh tariff.

PV01
The system designed for area PV01 has been calculated to cost £12,300, including the additional cost of angled PV framing to obtain the preferred 30 degree tilt, plus the cost of installation /labour cost and VAT. The payback analysis considers inverter replacement and annual maintenance plus the income generated from the Feed it Tariff (£20,500 over 25 years) and the energy saved on electricity bills (£10,200 over 25 years). Graph 10 indicates the payback to be in year 15 – 16, paying back £24,500 over the life of the FiT scheme. The remaining 10 years are regarded as profit which could be used for further installations or for energy efficient upgrades for other properties. The first year of electrical generation produces circa 2,455kWh/y, and on the 25th year, just above 2,177kWh/y is produced; (an 11% reduction in efficiency) as shown in Graph 11. Over the 25 year analysed timeframe, the designed system will produce 57,800kWh of electricity resulting in 30 tonnes of carbon dioxide emissions being saved,(in comparison to grid electricity). Graph 11 illustrates the electricity generation and carbon dioxide savings (compared to grid electricity), each year over the 25 year analysed period.
PV02

Economic analysis for PV02 is similar to that of PV01, the primary difference being smaller annual produced energy figure as a result of the change in orientation. The capital cost and payback period of the analysed PV system is calculated to be the same as that described in PV01 (see Graph 12). Over the 25 year life of the FIT scheme the PV system will generate 57,200kWh of electricity, £10,000 in savings on electricity bills, £20,300 from FIT income and will save 30 tonnes of carbon dioxide emissions (compared to grid electricity). Including costs associated with annual maintenance and replacement inverter, the overall income from the system has been calculated as £24,150. During the first year the modules will produce 2,426kWh/year, equating to £750 in income. The PV has the potential to contribute 72 per cent of the building’s electricity demand, with the energy generation decreasing until the 25th year where it produces just below 2,151kWh, this represents a 275kWh reduction, with the electricity contribution decreasing to 68 per cent. However, the income increases to £1,830 as a result of tariff inflation. The carbon dioxide savings start at 1.26 tonnes per annum and decrease to 1.12 tonnes per annum on the 25th year (see Graph 13).

PV03

The PV system designed for the area designated PV03, is larger than PV01 and 02. This additional area allows for extra PV panels, increasing the array from a 12 panel to a 14 panel system. The PV system is calculated to cost a total of £12,400; this cost includes PV system and inverter, additional angled framework, installation/labour and VAT. This system has the potential to generate up to 63,900kWh of electricity, £22,800 through the FIT income, £11,300 savings on the electricity bill and 33 tonnes of carbon dioxide saved (compared to grid electricity). The system for PV03 designed for block 5 generates all the electricity demand as calculated from the utility bills, plus an additional 14 per cent, therefore this system will also be generating £186 income from the export tariff over the 25 year FIT scheme. Total income generation with costs for a replacement inverter and allocation of finance for yearly PV panel maintenance equates to a total of £34,200 income from the designed PV system over the 25 years. Graph 14 charts the payback per year, and indicates the payback period to be in year 14.
The first year's production of energy for the PV system in PV03 is calculated to be 2,718kWh/y, generating a total of £852 and saving 1.42 tonnes of carbon dioxide (compared to grid electricity). The generation and carbon dioxide savings decrease annually to the 25th year where the system produces 2,400kWh, saving 1.25 tonnes of carbon dioxide (compared to grid electricity). The yearly income increases to £2,050, reflecting the inflation rate of the tariffs. Graph 15 charts the yearly generation, carbon dioxide savings, and the PV systems contribution to the buildings electricity requirements.

PV04
Economic analysis for PV04 is similar to that of PV03, the only exception being the annual electricity requirement for the building and the orientation of the area marked PV04. The utility bills provide data to suggest that electricity demand for block 9 is 4,186kWh/year. The capital cost of the analysed PV system is calculated to be the same as that described in PV03. The income generation is similar. However, the system for block 9 contributes 64 per cent of the building annual requirement, and this system will not benefit from the export tariff. This system will generate 63,400kWh and £27,700 over the 25 year analysed period, the financial income is based on the FiT, saving in electricity bill, cost for annual maintenance and the price for a replacement inverter, see Graph 16.

Over the 25 year life of the FiT scheme the system would save 38 tonnes of carbon dioxide emissions (compared to grid electricity). During the first year the modules will produce 2,691kWh/year and decreasing until the 25th year where they produce just below 2,760kWh/year, representing a 11 per cent reduction in efficiency. The carbon dioxide savings start at 1.40 tonnes per annum and decrease to 1.24 tonnes per annum on the 25th year. This is charted in Graph 17, which shows the electricity contribution of the PV system.
PV05
As the system selected for the area marked PV05 is identical to PV04, with the same orientation and number of panels. Graph 16 is also applicable to the payback information for PV05. A difference occurs in the estimated annual electricity requirement for block 11. During the construction of this report, no consumption data or billing information for block 11 was available; therefore, the annual energy demand for block 11 has been estimated based on the consumption data of blocks 3, 5 and 9. This has been calculated to be 3,319kWh, and the PV system is designed to produce 2691kWh/y in year 1, contributing 81 per cent, decreasing down to 2,386kWh/y, equating to a 72 per cent contribution in year 25, (see Graph 18).

Graph 18: PV05 - Yearly Electricity generated over carbon dioxide savings
6.4 17 ALBERT STREET

Overview
This five storey building constructed in the late 1990s houses a number of flats and is located close to Edinburgh’s Leith Walk. Figure 23 shows that the buildings falls outwith Leith’s conservation area (the conservation areas is outlined and shaded) therefore the PV array can be designed without the need to comply with more stringent planning procedures. The roof is of mansard design with two flanking chimneys. The PV analysis for the property will focus on the rear of the building, on the pitched part of the roof, as marked in Figure 24 and Figure 25.

Figure 23: 17 Albert Street, conservation map

Figure 24: 17 Albert Street aerial view

Figure 25: 17 Albert Street 3D high angle model

Orientation/azimuth: The rear of the building is facing at 5 degrees Southwest.

Roof pitch: Information from the technical drawings indicates that the pitched portion of the Southwest facing roof has a 35 degree tilt.

Roof area: As indicated in Figure 24, the area to be analysed is 72 m².

Shading: The roof area selected for analysis currently experiences no shading from neighbouring structures or foliage.
Estimated energy consumption

The annual electricity consumption for the communal areas within 17 Albert Street has been calculated from invoiced bills from the utility company. The information is subject to utility company calculations and end of year adjustments, and therefore the electricity consumption and cost per quarter has been even levelled out, providing no indication on consumption pattern over a calendar year. However, the more relevant data on annual consumption (both cost and energy) provides the basis by which a PV system can be designed. The annual consumption has been stated as 7,500kWh/year and £930 a year, including VAT and quarterly standing charges.

System options and selection:

As highlighted in Table 12, option 3 is the selected PV system, based on the system’s yearly produced energy and the cost of the complete system. This option provided a higher output for a similar overall cost compared to the other options analysed. The modules selected consist of 36x260W monocrystalline panels in 3 strings of 12 panels creating a 9.4Wp total power system using a 9.0kW inverter. Design simulations estimated that the system will produce over 7,500 kWh in its first year. Figure 26 indicates the panel distribution which avoids any ventilation pipes.

<table>
<thead>
<tr>
<th>Project - Building location</th>
<th>Usable roof area</th>
<th>Roof - Tilt/azimuth</th>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Phases</th>
<th>Number of modules</th>
<th>Power (Wp) per module</th>
<th>Total power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 Albert Street</td>
<td>72m²</td>
<td>35° &amp; 5° Southwest</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>36</td>
<td>255</td>
<td>9.2</td>
<td>1</td>
<td>9.0</td>
<td>3</td>
<td>7441</td>
<td>811</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Polycrystalline</td>
<td>Single</td>
<td>36</td>
<td>225</td>
<td>8.1</td>
<td>1</td>
<td>8.0</td>
<td>3</td>
<td>6539</td>
<td>807</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>36</td>
<td>260</td>
<td>9.4</td>
<td>1</td>
<td>9.0</td>
<td>3</td>
<td>7565</td>
<td>808</td>
</tr>
</tbody>
</table>

Table 12: System sizing using three module & inverter options – Property: 17 Albert Street

Economic analysis:

Results from design simulations on the selected PV system, indicate the annual electricity output to be over 7,500kWh (see Table 12), and the estimated annual electricity consumption for the communal areas of the property has been estimated at 7500kWh/year. Therefore, initially the system will generate 100% of the buildings electricity needs. However, over the life of the solar panel, the output will decrease; (see Graph 20). Over the 25 year analysed period, the system will generate less, requiring electricity from the grid to cover the shortfall. Based on the information analysed from the utility bills and in Table 12, the system will not produce enough additional electricity to benefit from the export tariff, however, with possible energy efficiency improvements or changes in occupant behaviour, the electricity requirement of the building may reduce below the PV’s generation potential, if this is the case, the system can benefit from the export tariff.

Graph 19 charts the investment and financial return from the selected PV system, based upon the capital cost of the system including the labour and VAT, and the income generated from the system through the Feed in Tariff and the saving made on the electricity bill. Initially the system will cost circa £19,500, or £31,000 inclusive of additional costs. Over the 25 year analysed period, the system will generate £50,600 from the FiT scheme and £31,400 from savings on the electricity bill, furthermore, the system will save a total of 93 tonnes of carbon dioxide emissions (compared to grid electricity).
Graph 19: Cumulative financial balance of the investment

Graph 20: Yearly Electricity generated over carbon dioxide savings
6.5 23 JAMESON PLACE – SHELTERED HOUSING

Overview

Constructed in 2000, 23 Jameson Place is part of three new domestic structures closing off the end of Jameson Place (Figure 28). The four storey building is within the Leith conservation area (see Figure 27). As such, additional design parameters will be considered when selecting the placement of the panels.

The property at 23 Jameson Place is one of PoLHA’s three sheltered housing complexes. The accommodation contains 31 self-contained flats ranging from 1 to 2 bedrooms, all with bathroom and fitted kitchen. There are also communal facilities, including a lounge, kitchen and laundry facilities, CCTV, and an elevator providing access to all floors. These properties are specifically designed for people over 60, and are staffed by a scheme co-ordinator to support the residents. The electricity generated by the addition of the PV system will be designed to reduce the buildings dependence on grid electricity.

Orientation/azimuth: The rear of the building overlooking the communal garden area is orientated 15 degrees Southwest. This falls within the desired design parameters for the optimum building orientation to maximise the solar collection of PV panels.
Roof pitch: In the absence of detailed construction drawings, the pitch of the roof marked in Figure 29 has been calculated to be between 30 and 35 degrees.

Roof area: The area of roof highlighted in Figure 28 and Figure 29 has been selected for PV placement. This location satisfies two key requirements. Firstly this portion of the roof provides an uninterrupted South facing platform, additionally, as the building is with the Leith conservation area, and the application of a PV system will require planning approval, the PV design is best situated away from the front elevation and in a position that is not visible from the street level. To further satisfy the planning requirements the PV area has been designed to be positioned centrally within the identified roof area, with a minimum distance of 1 metre away from the edge of the roof. This area has been calculated to be 142 m$^2$.

Shading: The roof area is currently not subject to any shading from neighbouring structures or foliage.

Estimated energy consumption:
Graph 21 has been generated using 13 months of electricity bills issued by the utility company to the Port of Leith Housing Association. Many of the meter readings obtained from the billing information have been based upon estimates; however, this data still provides an indication of the quarterly and annual electricity requirements for 23 Jameson Place. The total electricity requirement over an annual cycle has been estimated to be 58,000kWh, with peaks in the winter and lower consumption levels in the spring/summer as expected. Based on the stated electricity tariff plus value added tax, the total cost of the electricity consumed of the 2010 -2011 period has been calculated at £5,900, including the additional standing or quarterly charges imposed by the utility company.

System options and selection:
The Monocrystalline 39 x 255Wp set of modules, along with a 9kW inverter is the selected system for further analysis (see Table 13). The system is selected for its higher produced annual energy output in relation to the size of roof available and keeping the system below 10kWp. Option 3 had a similar calculated capital cost as the other 2 options design for this site. The system can produce around 8,000kWh of energy per year. Figure 30 illustrates the modelling design layout of PV panels on the portion of roof earlier identified in Figure 28 and 29.

<table>
<thead>
<tr>
<th>Project - Building location</th>
<th>Usable roof area</th>
<th>Roof - Tilt/azimuth</th>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Phases</th>
<th>Number of modules</th>
<th>Power (Wp) per module</th>
<th>Total power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 Jameson Place</td>
<td>142m²</td>
<td>30-35° &amp; 15°</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>39</td>
<td>250</td>
<td>9.8</td>
<td>1</td>
<td>8.0</td>
<td>3</td>
<td>7783</td>
<td>798</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>2</td>
<td>Polycrystalline</td>
<td>Single</td>
<td>39</td>
<td>240</td>
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<td></td>
<td></td>
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<td>3</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>39</td>
<td>255</td>
<td>9.9</td>
<td>1</td>
<td>9.0</td>
<td>3</td>
<td>8020</td>
<td>806</td>
</tr>
</tbody>
</table>

Graph 21: Electricity consumption for 23 Jameson Place 2010 – 11

Table 13: System sizing using three module & inverter options – Property: 23 Jameson Place
Economic analysis:

Based on an electricity requirement of 58,000kWh/year, design simulations calculate the total generated energy from the PV to fulfill 14% of the building’s annual electricity needs. This figure is subject to change in relation to reductions in panel efficiency over the life of the system (see Graph 23). The initial capital cost of the materials for the system in option 3, have been calculated to be circa £21,000. With the addition of labour, installation, delivery and charges including value added tax, the total cost for the system is calculated to be circa £34,000. Taking into consideration the Feed in Tariffs, the cost of saved electricity and the other cost for maintenance and inverter replacement, the estimated payback period for this installation would be between year 13 and 14 of the scheme as illustrated in Graph 22.

Based on the post March 2012 Feed in Tariff of 16.8p/kWh for systems under 10kWp, the cost analysis of the PV design indicates that the system would accumulate approximately £53,700 in revenue, which in turn may be used for panel replacement or fabric maintenance/improvements, if and when required. The savings made through the production of onsite electricity, not paying utility company bills equates to a total circa £33,300 over the 25 years. Over the 25 year analysed period, the system will have saved 98 tonnes of carbon dioxide compared to using grid electricity.

Graph 23 shows how the initial energy production of the PV system calculated at 8,000kWh decreases 11% over its lifetime, which is also reflected in the carbon emission offset from 4.18 tonnes saved in year one, decreasing to 3.70 tonnes in year 25. A slightly larger power output system could have been designed for 23 Jameson Place. However, as the PV systems increase over 10kWp the Feed in Tariff structure reduces the amount of financial incentive per kWh. Furthermore with current grid connection application it is advisable to keep the system below a 10kW array.
6.6 3 ACADEMY PARK – SHELTERED HOUSING

Overview:
Constructed in 1993, adjacent to Leith Academy secondary school, and rendered in a distinctive terracotta coloured harling, this four storey building is one of PoLHA’s three sheltered housing complexes. The accommodation contains 38 self-contained 1 bedroom flats with communal facilities, including a lounge, kitchen, laundry room, and an elevator providing access to all floors. The property is not within the Leith conservation area (see Figure 31), therefore, allowing for the unrestricted placement of panels within 1 metre from the building’s facade, as indicated in Figure 33. The electricity generated by the addition of the PV system will be designed to provide as much electricity as practicable, so as to reduce the building’s dependence on grid electricity.

Orientation/azimuth: The building is orientated 35 degrees Southwest, shown in Figure 32.

Roof pitch: No drawings were available during the compilation of this document; therefore, the roof pitch has been calculated to be 35 degrees, using estimations.

Roof area: With no construction drawings available for accurate measurements, the area of roof highlighted in Figure 32 and Figure 33 has been calculated to be 115 m².

Shading: with the building’s Westerly orientation, the gable ended portion of the building on the right of Figure 33 will cast a shadow over the main portion of the roof; therefore, the area for PV placement has been reduced to compensate for shading.
Estimated energy consumption:
The property at 3 Academy Park has two electricity meters, an off peak meter and a day/night meter. The electricity consumption through each of these meters is charted in the Graphs 24 and Graph 25. The energy consumption and costs data has been extracted from utility bills issued to PoLHA. The information on energy used each quarter is derived from estimated meter readings, and subject to subtle corrections implemented by the utility company. The annual electricity demand based on the day/night meter has been calculated to be 19,351kWh/year from the night meter, and 65,600kWh/year from the day meter, the cost for the electricity used through the day/night meter, including VAT and quarterly charges has been calculated to be £8,600/year. Energy demand through the off peak meter (as illustrated in Graph 25) has been calculated to be 53,200kWh/year costing £3,261 a year. The combined energy consumption, as billed to PoLHA for 3 Academy Park has been calculated as 138,000kWh/year costing £11,840/year. The annual energy consumption and cost are parameters by which the economic analysis for the PV system will be designed.

System options and selection:
Many PV systems were designed, modelled and simulated for 3 Academy Park, and Table 14 lists the three preferred options. Options 1 to 3 were selected based on their high produced energy annual output, keeping below the 10kWp threshold to obtain a higher Feed in Tariff rate. The three systems differ in panel technology, number of modules and power per module. Option 1 was chosen as the preferred PV system, based on a combination of produced energy output and price of system. Although option 3 produces more energy per year, the price difference between system 1 and 3 increased significantly, not proportionate to the increase in energy capacity. The large amount of uninterrupted roof area available allowed for the addition of 3 additional panels (from 39 in option 3 to 42 in option 1), to reduce the price and maintain a relatively high capacity system, with a total produced energy of 7718kWh/year.
The panel array design is depicted in Figure 34, the module layout is based upon estimated roof area as no plans were available, a more detailed design and placement should be made when contracting and obtaining quotes from MCS accredited installers.

Table 14: System sizing using three module & inverter options – Property: 3 Academy Park

<table>
<thead>
<tr>
<th>Project - Building location</th>
<th>Usable roof area</th>
<th>Roof - Tilt/azimuth</th>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Phases</th>
<th>Number of modules</th>
<th>Power (Wp) per module</th>
<th>Total power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Academy Park</td>
<td>115m²</td>
<td>35° &amp; 35° Southwest</td>
<td>1</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>42</td>
<td>235</td>
<td>9.9</td>
<td>1</td>
<td>8.0</td>
<td>3</td>
<td>7718</td>
<td>782</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Polycrystalline</td>
<td>Single</td>
<td>42</td>
<td>230</td>
<td>9.7</td>
<td>1</td>
<td>8.0</td>
<td>3</td>
<td>7284</td>
<td>754</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Monocrystalline</td>
<td>Single</td>
<td>39</td>
<td>255</td>
<td>9.9</td>
<td>1</td>
<td>8.0</td>
<td>3</td>
<td>7843</td>
<td>789</td>
</tr>
</tbody>
</table>

Economic analysis:

The System in option 1, (see table 14) has been calculated to cost between £17,800 and £18,000. Including labour and VAT the total investment cost is circa £29,000. This system is designed to generate a total of approximately 181,800kWh, and saving 94 tonnes of carbon dioxide (compared to grid electricity) over the 25 year analysed period. The system is designed to qualify for the £0.168/kWh Feed in Tariff as it is below 10kWp. Over the 25 year period the system could generate £51,700 from FiT income, and £32,000 through savings on the electricity bills. Graph 26 shows that the total pay-back in years for this system is between year 12 and 13, and will continue earning with the Feed in Tariff until the end of the scheme. Graph 26 shows the balance between investment and return, including maintainance, inverter replacement, electricity tariff, and Feed in Tariff inflation. Graph 27 charts the panel’s drop in efficiency over the 25 year analysed period. Similar to many other panel systems, the output of the the PV in option 1, will drop 11 per cent in output over the 25 year period. From 7,718kWh/year in year 1 down to 6,843kWh/year in year 25, the carbon dioxide savings will also reduce, from 4.02 tonnes in year 1, down to 3.57 in year 25.
6.7 34 LORNE STREET

Overview
This L shaped four storey building on the corner of South Lorne Place and Lorne Street houses block numbers 2 to 8, and 28 to 34, with the entrance to Block 34 on Lorne Street as indicated in Figure 36. The building’s distinctive red brick and white rough render, with a feature turret, separate it from the earlier 1900s dwellings, in the nearby conservation area. The front elevation of the building is facing Southward, with large area of roof well positioned for the application of PV equipment. The building is not in the Leith conservation area, (see Figure 35) and therefore, the design of the PV system will be based on the available space as highlighted in Figure 36 and Figure 37.

Figure 35: 34 Lorne Street location in conservation map

Orientation/ azimuth: The front elevation of the building facing on to Lorne Street, is orientated 27 degrees Southwest.

Roof pitch: The roof is estimated to have a pitch of 35 degrees. This figure is based on calculations as no detailed drawings were available at the time of the study. More accurate measurements should be taken at time of project realisation.

Roof area: The area highlighted in Figure 36, has been estimated to be 132 m², and the area directly above block 34 has been estimated to be 64 m². This portion of the roof is interrupted by the pitched roof of the porch for the main entry door.
Shading: A field survey has revealed no nearby shading from buildings or foliage that will currently or in the near future adversely affect the performance of proposed panels. A proposed PV array will be positioned around the pitched roof on the porch.

Estimated energy consumption:
The quarterly electricity consumption for the communal areas within 34 Lorne Street is charted in Graph 28. This data has been extracted from electricity bills as issued to PoLHA from 2010 and 2011. Although based on estimated meter readings, the data provided a good indication of the electricity consumption pattern over a 12 month period.

Graph 28: Electricity consumption for 34 Lorne Street 2010-2011

The results in Graph 28 represent a typical consumption pattern for electrical energy (kWh) over the first three quarters, with the largest consumption within the winter months; however, the results show an unexpected rise in consumption towards the end of the displayed period. Without the use of sub-metering, it is uncertain why there is an increase in electricity demand over the summer period, this may be attributed to the estimation procedure by the utility company. The total annual consumption for the period August 2010 to August 2011 is 2,420kWh/year, with a cost of £380, calculated from the electricity bills, this figure and the cost (£) information in Graph 28 are inclusive of VAT and standing charges. This data provides the basis by which to size the PV system to cover as much of the electricity requirement as possible.

System options and selection:
Table 15 lists the preferred three systems, based on modelling their performance, and simulating the yearly estimated solar irradiance. The best performing systems, applicable to the roof dimensions and below the 10kWp were shortlisted, so to receive a larger portion of the new Feed in Tariff, and still satisfy the buildings electricity requirements. The key differences amongst the three systems in table 15, is size of inverter and the power per module, and ultimately option number 3 was chosen for its cost-to-produced energy ratio. Although, option 3 does not have the highest produced annual output, the cost of the system is significantly lower than those calculated to have only marginally higher outputs.

<table>
<thead>
<tr>
<th>Project - Building location</th>
<th>Usable roof area</th>
<th>Roof - Tilt/azimuth</th>
<th>Option No.</th>
<th>Solar panel Technology</th>
<th>Phases</th>
<th>Number of modules</th>
<th>Power (Wp) per module</th>
<th>Total power (kWp)</th>
<th>Number of inverters</th>
<th>Size (kW)</th>
<th>Strings</th>
<th>Produced Energy (kWh/y)</th>
<th>Specific Production (kWh/kWp/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 Lorne Street</td>
<td>132m² available, using 55m²</td>
<td>35° &amp; 27° Southwest</td>
<td>1</td>
<td>Monocrystalline Single</td>
<td>16</td>
<td>250</td>
<td>1.6</td>
<td>2.6</td>
<td>2</td>
<td>3.8</td>
<td>2</td>
<td>3076</td>
<td>769</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Monocrystalline Single</td>
<td>16</td>
<td>230</td>
<td>1.7</td>
<td>2.3</td>
<td>2</td>
<td>3.3</td>
<td>2</td>
<td>2923</td>
<td>794</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Monocrystalline Single</td>
<td>16</td>
<td>240</td>
<td>1.8</td>
<td>3.6</td>
<td>2</td>
<td>3.8</td>
<td>2</td>
<td>3005</td>
<td>782</td>
</tr>
</tbody>
</table>

Table 15: System sizing using three module & inverter options – 34 Lorne Street
Figure 38 indicates the proposed configuration of the panels according to the required number of strings and in line with the roof geometry and constrains, for example, the dormer roof structures for the main entrance door. The panel layout is positioned directly above the entrance to block 34, the system in option 3 is designed to provide block 34 with all of its electricity requirements, however, with the large amount of available roof area on the building, a larger system can be designed if the required electricity is deemed to be higher.

Economic analysis:
The cost of the designed PV system based on option number 3 from Table 15 has been calculated to be circa £8,100. The total costs including associated installation prices plus VAT has been calculated to circa £13,000. Based on the utility bills, the system is over designed, firstly to cover all of the buildings communal electricity requirements with the possibility to export the extra electricity generated. Based on the Feed in Tariff and the systems design, the array has the potential to generate £900 on income for the first year, increasing each year, generating £2,000 in year 25. Over the 25 year analysed period, with the retail index price, and the tariffs increases, the system has the potential to generate circa £30,000 in income, this figure is inclusive of the income through the Feed in Tariff scheme, the export tariff scheme, and the savings made by generating onsite electricity compared to the annual utility bill.

Graph 30 illustrates the investment and income balance forecasted over the 25 year FiT scheme, and based upon 21p for <4kWp systems (post March 2012). The estimated payback period for this installation would be between year 13 and 14 of the scheme. This calculation takes into consideration other payments incurred such as a replacement inverter and yearly maintenance, but a more detailed capital cost should be made when contracting and obtaining quotes from MCS accredited installers. Given the size of roof available and building orientation, a larger PV system could be designed, however, the price of the PV systems are closely linked to the power per module (Wp), which in turn influences the kWh/year output of the system. The additional generation potential could be exported back to the grid, therefore, benefitting from the 3.1p export tariff. Similarly, several smaller systems could be design to assist with the electricity requirements of the other blocks in the building.

The calculated annual produced energy of the PV system generates enough electricity to supply the current estimated electricity requirement for the communal area of the building, and even with the 11 per cent decrease in energy output over the 25 years, the PV system still generates enough electricity to cover the buildings energy demand. Over the 25 year period the system has the potential to generate 70,700kWh saving 37 tonnes of carbon dioxide (compared to grid electricity). Graph 30 shows how initial energy production estimated at 3,005kWh/year decreases down to 2,663kWh/year, this is also reflected in the carbon emission offset from 1.56 tonnes saved in year one down to 1.39 tonnes in year 25.
Graph 29: Cumulative financial balance of the investment

Graph 30: Yearly Electricity generated over CARBON DIOXIDE savings
6.8 108 CONSTITUTION STREET

Overview

Constructed in 2000, and located on the corner of Constitution Street and Coatfield Lane, this building provides the offices for the Port of Leith Housing Association.

Orientation/azimuth: The building is positioned 70 degrees Southeast, this is close to a due East positioning. The building is not ideally placed for the application of PV equipment.

Roof pitch: The inverted pitched roof of the building requires the PV array to be positioned on the back portion of the roof. Furthermore, the roof is angled at a 1 degree runoff, towards the centre. This is not an optimum condition, and will require additional framing and PV angling support to increase the tilt to the desired 30 degree.
Roof area: The roof is broken up by multiple service structures, including flues, smoke ventilation system, roof light/access hatch and housing for the elevator mechanics. These structures divide the usable area into three areas, illustrated in Figure 40, and reduces the available area to a total of 36.6 m$^2$.

Shading: Due to the Easterly building position, the multiple service structures dividing the available PV placement area will cast shadows onto two of the three PV placement areas. The parapet structure will cast shadows onto the other PV placement area, further reducing the PV efficiency and energy output. Removing the areas affected by shading will reduce the available PV placement area to 4 m$^2$.

The building orientation, roof design and location of existing roof structures/apertures are not ideal for the application of PV equipment. Initial analysis on PV design and simulations for the building suggest that the PV equipment will not perform as efficiently as the other systems discussed in the previous properties, shading and additional costs associated with raising the PVs to the desired 30 degrees make the system design uneconomical for this building.
7.0 ANALYSIS OF “RENT A ROOF” SCHEME

Since the introduction of the Feed in Tariff scheme in April 2010 a number of installers have begun to offer free solar panels to home owners or RSLs who find it difficult to fully invest and obtain the capital cost or simply feel it would be easier for an external company to manage such installation. These installers and in some cases developers can install the panels in exchange for the home owner leasing their roof space which allows them to claim the Feed in Tariff payments for the term of the lease (25 years).

The scheme involves granting a legal interest (the solar panel lease) in the property to the installer. If the owner has a mortgage then the lender consent will be needed. There are two reasons for this, firstly it is a breach of the conditions of most mortgages to grant a lease of all or part of your property without the lender’s consent and secondly the lease will not be binding on the lender and can be terminated by the lender. In order to make the process of obtaining consent more simple it is advisable that property owners consult the Council of Mortgage Lenders (CML) [8]

Some advice on looking at “Rent a Roof”

It is advisable that the RSL enters into a lease with the installer, who should draft this document. The home owner and in some cases the RSL, should take legal advice once commencing negotiations, making sure it is a viable and non-confictive scheme. Once approved by the property owner, the lease will need to be presented to the lender (Bank or Building Society) who will verify it doesn’t infringe the initial mortgage agreements.

Some solar panel leases require the home owner to pay an annual maintenance charge. The Council of Mortgage Lenders suggests that the maximum charge is £60 per annum. The installer must be responsible for insuring the panels and the equipment are in good operating order and comply perfectly with health and safety regulations. The lease must allow for the lender, in the event that it has to repossess and the presence of the panels is affecting its ability to sell, to remove the panels and terminate the lease without penalty.

Once the lease is accepted, the installer makes an application, on behalf of the borrower, to the lender. The installer must provide evidence of its accreditation with MCS, signed authorisation from the home owner for the lender to communicate directly with the installer, a copy of the lease and the contact details of the installer.

In terms of the economic elements of the scheme there needs to be a clear understanding of who will be paying and receiving what, and when those agreements perish or are modified. In many cases the electricity generated by the panels is used and consumed by the property owner for free but in some cases the companies will sell the energy at a reduced price to the home owner. The FiT received from the government will be paid to the company who has made the initial investment and will be looking to pay back their capital cost. Some of the issues around the “rent a roof” schemes that are being looked at pose many questions both technical and economic which different companies will address with certain approaches. For example:

- Maintenance:
  - Who will be paying for the maintenance of the panels?
    Most of the time this is covered by the company, the quality and frequency should be questioned.
  - What are the implications of damaging the existing roof of the property?
    This should be discussed with building property insurance providers who have to be informed of the installation and what it may cover in case of damage incurred. In many cases insurance companies will cover but will increase payments too.
  - In case of inverter replacement, who pays the fee?
    Inverters and other equipment replacement should be paid by the installers; this should be revised and clarified.
  - What level of disruption will there be from the company’s installers during the scheme?
    There may be times in which cleaning and wire or meter replacement takes place and this could be once a year or in a case by case scenario.
Economic:
- The electrical energy produced will be used in the property; what happens if there are surpluses and there is an opportunity to sell back to the grid? Who receives the incentive?
- Will there be some tariff allocation to the property owner or will all the incentives go directly to the company?

Many more questions can arise from the schemes and companies differ in the packages and elements which they will offer to make clients interested.

The advantage of receiving such a service is that in many cases the installation problems and maintenance of such technology can be minimal. Rent a roof scheme would appear to be a good way of obtaining renewable energy equipment fitted onto the dwelling which will partially or wholly fulfil a dwelling’s needs, saving on energy from the grid and also reducing reliance on fossil fuels. The capital cost which can be substantial depending on the size and complexity of the system, is absorbed by the Rent a Roof installer.

The disadvantages of these schemes vary from company to company. Leasing any part of a home, especially for such a fixed timeline, can be a liability which may affect the owners ability to move from the property. The 25 year FiT scheme can present problems such as; tenant wanting to sell and relocate, assurance that maintenance of the panels will be constant (which in many cases should be as it’s in the installers interest to produce more energy to obtain more FiT), company’s insolvency – if the company’s ceases trading, what would happen to the panels, would it be a case of the company taking such installation off, or do they remain on the roof?

Many companies convince property owners by indicating that after the 25 years in which the FiT has been paid the panels will remain on the roof and free energy will continue to be sourced. The problem with this is that the owner then takes over liability for maintenance and inverter replacements. It is also evident that the efficiency and performance of such installations will diminish and their electricity production will lower considerably.

Economically speaking, with the FiT in place, the pay back of the capital costs of many systems is generally paid within the first quarter or half way through the 25 year FiT scheme. This means a great deal of money (sometimes more than half of the FiT) that will be a profit to the company, making it a very good overall investment.

This report clearly indicates that all RSLs should be careful in committing into a Rent a Roof scheme as it is a long term commitment that may in the long run pose problems such as extra costs or poor standards of maintenance. It is therefore recommended that RSLs, where possible, secure the capital funding to install PV equipment themselves, and take advantage of the FiT income as a secure and lucrative investment.

The recent announcement from the government confirmed that PV solar installations after 3rd March 2012 will get a lower FiT rate of 21p/kWh instead of the old 43.3p/kWh. There is however still uncertainty about whether systems installed between 12 December 2011 and 3 March 2012 would get 43.3p or 21p/kWh. This is subject to an array of complex on-going legal challenge with the government. In short, the new FiT rate for PV systems discussed in this report, plus the introduction of the new multi-installation tariff rates, which applies a reduced tariff to generators with 25 or more solar PV installations, may make schemes such as ‘Rent-a-Rooftop’ unviable, therefore the companies who previously offered the deal, might no longer find it financially attractive to do so, or harsh changes in ‘Rent-a-Rooftop’ contracts are to be expected.
8.0 CONCLUSION, SUMMARY OF RESULTS

This report has highlighted the technical and economic issues pertaining to the sizing and specifying of solar photovoltaic systems onto existing domestic dwellings and also a number of legislative constraints which RSLs need to be familiar with before any installation takes place. 13 PV systems have been designed and discussed for eight locations within the Port of Leith Housing Association’s portfolio, with the objective of providing PoLHA’s with a clear understanding of all the constraints and technical issues surrounding the installation of PV technology, before committing to a 25 year investment. A full breakdown of energy and income generation, cost of systems, and carbon dioxide savings are detailed in Table 16.

The analysis process included modelling a number of PV panel sizes and technologies along with inverter size options for each building or for each block within a building. The modelling mechanism takes influence from each buildings orientation, roof tilt, size of availability roof area and any shading that impacts upon the roof. Each PV and inverter option was simulated obtain a yearly output of electricity and the number of panels required to achieve different output levels. The selection of the ‘best fit’ PV system was based upon the annual kilowatt/hour output to cost ratio. All the case studies analysed in the document are subjected to individual constraints, either with roof space, appropriate orientation, roof tilt or their location in relation to the City of Edinburgh conservation areas.

The buildings that don’t reach the required 30 to 40 degree roof tilt require additional mounting rails to reach the preferable design angle in order to generate as the higher end of possible designed energy production. The five proposed PV placements at Sandport Way represent the only example where such additional framework is required. For Sandport Way and all the properties with designed PV equipment it is recommended that a further structural analysis is carried out on the roof loads and their capacity to support the modules extra weights as well as the correct fixing.

One of the main drivers for making this investment work is government’s incentives in the form of a Feed in Tariff. Without this incentive for the production and export of energy the pay back of such installations would rely only on the energy savings from the installation. It is for this reason that any changes to these tariffs can affect substantially a decision to invest with longer pay back periods; this is further discussed in Appendix A. To fully achieve the new FiT for the eligible systems, it is important that an EPC certificate showing a rating of level D or above is provided as part of the FiTs application, applicable to the building to which the solar PV installation is attached or wired to provide electricity.

RENT A ROOF SCHEME

To summarise the discussions relating to “rent a roof”, conversations with companies conducting such projects have indicated that they were under extreme pressure to deliver installations before the 12th of December 2011 and envisaged fewer installations in 2012 with the reduction of the tariff. In general terms the companies are most affected by the changes to this scheme because of the less income they would receive. Some companies are changing their policies and are in some cases no longer offering free energy and are charging the home owner a small tariff and/ or are no longer keeping to many promises stated before, for example; maintenance regimes and insurance or liability of damaged to roofs. This risk factor makes “Rent a Roof” companies less reliable especially over long periods of economic uncertainty.

An alternative option to the ‘rent a roof’ scheme, would involve securing the capital costs through bank loans instead of committing to long term scheme. There are also issues under RSL owned properties of prepaid meters and how that would tie into the installation of PV panels. Future government finance incentives like the ‘Green Deal’ introduce the concept of repaying the cost of a loan through the money saved on the energy bill by the addition of the energy saving equipment. The equipment be eligible for ‘Green Deal’ finance are still be finalised, solar panels will only be covered if they meet the Green Deal’s ‘golden rule’, which requires the cost of the installation to be recouped over a certain amount of time through lower energy bills, probably 25 years. This particular scheme is still under consultation, and the finer details surrounding its operation within RSL properties and the relationship between the landlord and dwelling occupant is still to be clarified.
### Table 16: Summary of results for each property in section 6

<table>
<thead>
<tr>
<th>Property in conservation area</th>
<th>58 Restalrig</th>
<th>56 Restalrig</th>
<th>74 Ferry Road</th>
<th>1 Sandport way</th>
<th>3 Sandport way</th>
<th>5 Sandport Way</th>
<th>9 Sandport Way</th>
<th>11 Sandport Way</th>
<th>17 Albert Street</th>
<th>23 Jamieson Place</th>
<th>3 Academy Park</th>
<th>34 Lorne Street</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year payback occurs</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Total 25 year PV generation (kWh)</td>
<td>190,648</td>
<td>177,269</td>
<td>73,495</td>
<td>57,840</td>
<td>57,160</td>
<td>63,978</td>
<td>63,401</td>
<td>63,401</td>
<td>178,151</td>
<td>188,919</td>
<td>181,813</td>
<td>70,736</td>
</tr>
<tr>
<td>Total electricity export back to grid (kWh)</td>
<td>-</td>
<td>37,944</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4,178</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10,236</td>
</tr>
<tr>
<td>First years generation (kWh/year)</td>
<td>8,093</td>
<td>7,525</td>
<td>3,120</td>
<td>2,455</td>
<td>2,427</td>
<td>2,716</td>
<td>2,692</td>
<td>2,692</td>
<td>7,563</td>
<td>8,016</td>
<td>7,718</td>
<td>3,003</td>
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<tr>
<td>Last years generation (kWh/year)</td>
<td>7,176</td>
<td>6,672</td>
<td>2,766</td>
<td>2,177</td>
<td>2,152</td>
<td>2,408</td>
<td>2,386</td>
<td>2,386</td>
<td>6,706</td>
<td>7,107</td>
<td>6,843</td>
<td>2,663</td>
</tr>
<tr>
<td>Contribution of PV to building electricity demand year 1</td>
<td>98%</td>
<td>135%</td>
<td>7%</td>
<td>10%</td>
<td>72%</td>
<td>114%</td>
<td>64%</td>
<td>81%</td>
<td>101%</td>
<td>107%</td>
<td>103%</td>
<td>103%</td>
</tr>
<tr>
<td>Contribution of PV to building electricity demand year 25</td>
<td>8%</td>
<td>120%</td>
<td>6%</td>
<td>9%</td>
<td>64%</td>
<td>101%</td>
<td>57%</td>
<td>72%</td>
<td>90%</td>
<td>95%</td>
<td>92%</td>
<td>110%</td>
</tr>
<tr>
<td>Price of equipment</td>
<td>£18,199</td>
<td>£19,484</td>
<td>£8,598</td>
<td>£7,620</td>
<td>£7,658</td>
<td>£7,658</td>
<td>£7,658</td>
<td>£7,658</td>
<td>£13,484</td>
<td>£13,484</td>
<td>£21,218</td>
<td>£17,954</td>
</tr>
<tr>
<td>Total cost system, install and VAT</td>
<td>£30,574</td>
<td>£31,565</td>
<td>£13,930</td>
<td>£12,344</td>
<td>£12,344</td>
<td>£12,344</td>
<td>£12,344</td>
<td>£12,344</td>
<td>£34,373</td>
<td>£34,373</td>
<td>£44,085</td>
<td>£23,185</td>
</tr>
<tr>
<td>Income generation from feed in tariff</td>
<td>£54,239</td>
<td>£50,433</td>
<td>£26,136</td>
<td>£20,569</td>
<td>£20,327</td>
<td>£22,752</td>
<td>£22,547</td>
<td>£22,547</td>
<td>£50,683</td>
<td>£50,683</td>
<td>£53,747</td>
<td>£51,725</td>
</tr>
<tr>
<td>Total 25 year savings on electricity bill (based on current tariff and yearly inflation)</td>
<td>£33,604</td>
<td>£24,836</td>
<td>£12,954</td>
<td>£10,195</td>
<td>£10,075</td>
<td>£11,277</td>
<td>£11,175</td>
<td>£11,175</td>
<td>£31,401</td>
<td>£33,299</td>
<td>£32,046</td>
<td>£10,785</td>
</tr>
<tr>
<td>Income generation from 25 years of exporting electricity</td>
<td>-</td>
<td>£1,914.21</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>£185.97</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>£503.59</td>
</tr>
<tr>
<td>Total income over 25 years minus costs for 25 years of maintenance</td>
<td>£80,873</td>
<td>£70,213</td>
<td>£32,840</td>
<td>£24,510</td>
<td>£24,148</td>
<td>£27,360</td>
<td>£27,679</td>
<td>£27,679</td>
<td>£75,115</td>
<td>£80,076</td>
<td>£76,802</td>
<td>£30,194</td>
</tr>
<tr>
<td>First years income</td>
<td>£2,169</td>
<td>£1,882</td>
<td>£967</td>
<td>£761</td>
<td>£752</td>
<td>£852</td>
<td>£834</td>
<td>£834</td>
<td>£2,027</td>
<td>£2,148</td>
<td>£2,069</td>
<td>£949</td>
</tr>
<tr>
<td>Last years income</td>
<td>£5,300</td>
<td>£4,703</td>
<td>£2,457</td>
<td>£1,853</td>
<td>£1,832</td>
<td>£2,051</td>
<td>£2,032</td>
<td>£2,032</td>
<td>£4,953</td>
<td>£5,249</td>
<td>£5,054</td>
<td>£2,287</td>
</tr>
<tr>
<td>First year carbon dioxide saving (tonnes)</td>
<td>1.19</td>
<td>1.11</td>
<td>0.72</td>
<td>0.65</td>
<td>0.63</td>
<td>0.72</td>
<td>0.72</td>
<td>0.72</td>
<td>1.13</td>
<td>1.17</td>
<td>1.17</td>
<td>0.72</td>
</tr>
<tr>
<td>Last year carbon dioxide saving (tonnes)</td>
<td>3.55</td>
<td>3.48</td>
<td>1.44</td>
<td>1.33</td>
<td>1.29</td>
<td>1.42</td>
<td>1.40</td>
<td>1.40</td>
<td>3.94</td>
<td>3.89</td>
<td>3.89</td>
<td>1.39</td>
</tr>
<tr>
<td>Total carbon dioxide saving (tonnes)</td>
<td>99.35</td>
<td>92.38</td>
<td>38.30</td>
<td>30.14</td>
<td>29.79</td>
<td>33.34</td>
<td>33.04</td>
<td>33.04</td>
<td>92.84</td>
<td>98.40</td>
<td>94.75</td>
<td>36.86</td>
</tr>
</tbody>
</table>
9.0 REFERENCES


9. Department of energy & Climate Change – Feed-In tariffs scheme: consultation on Comprehensive review Phase 1 – tariffs for solar PV.


12. Town and Country Planning (General Permitted Development) (Domestic Microgeneration) (Scotland) Amendment Order 2009 and came into force on 12th March 2009.

13. Town and Country Planning (General Permitted Development) (Domestic Microgeneration) (Scotland) Amendment Order 2010 and came into force on 8th March 2010.


15. Satellite images, courtesy of TerraMetrics Map data ©2012 Google

16. 3D high angel modelling, courtesy of Infoterra Ltd 2012 and Bluesky © 2012 Google

17. Conservation maps, courtesy of Crown Copyright and database right 2011. Ordnance Survey License number 100023420

18. Street view of properties, courtesy of Google maps © 2012 Google
10.0 FURTHER READING:


2. Draft IEC 62446 Ed.1 ‘Grid connected PV systems – Minimum system documentation, commissioning tests and inspection requirements’.


6. PV module costs supplied by Mitsubishi UK Ltd and Cleaner Air Solutions UK Ltd. 2011 prices.
11.0 Appendix A – INCOME ADJUSTMENT BASED ON EPC SCORE

On completion of this document in February 2012, DECC/OFGEM published the responses to the highly debated review of the Feed in Tariff. Along with the reductions in tariff, additional conditions were announced, which will influence eligibility for the Feed in Tariff that would have otherwise been awarded based solely upon the size of the system. The addition of the ‘Energy Efficiency’ section to the April 2012 tariff structure will impact upon any building seeking the Feed in Tariff, but which has not achieved an EPC rating D or above. This is discussed in section 4.2, but summarised in Table 17.

This document has calculated the paybacks and economic figures using the tariffs that come into effect in April 2012, in respect of PV system specified for each building. The government has introduced a requirement for ‘Energy Efficiency’ EPC D or higher as a strategy within the FiT mechanism to encourage owners to take steps to improve the energy efficiency of their building before installing renewable microgeneration technology.

<table>
<thead>
<tr>
<th>Solar PV System Size:</th>
<th>Generation tariff (p/kWh) After April 2012</th>
<th>Tariff change is EPC is below D (p/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4kWp or less (Retrofit)*</td>
<td>21.0</td>
<td>9.0</td>
</tr>
<tr>
<td>4kWp or less (New build)</td>
<td>21.0</td>
<td>9.0</td>
</tr>
<tr>
<td>4kWp - 10kWp(other than stand alone)**</td>
<td>16.8</td>
<td>9.0</td>
</tr>
<tr>
<td>10kWp - 50kWp(other than stand alone)**</td>
<td>15.2</td>
<td>9.0</td>
</tr>
<tr>
<td>50kWp – 100kWp(other than stand alone)**</td>
<td>12.9</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Table 17: Current and new feed-in tariffs introduced after a government consultation

* A retrofit installation is defined as any installation fitted to or wired to an existing building.
** A stand alone system is defined as not attached to or wired to a building in order to provide electricity to that building, e.g. solar energy farms wired directly into the grid.

Summary Table 18 shows the consequences of such decreases in tariffs by calculating the new payback periods and decrease in income. The lower tariff will come into force from 1 April 2012 and places the onus of those seeking the benefit of the FiT to upgrade less energy efficient buildings before submitting the application so to obtain the highest applicable tariff. Otherwise the system will receive the lower tariffs imposed.

These reductions affect the amount of income that a system can obtain on a yearly basis for every kWh generated by the installation. The case studies in Section 6.0 of this document used the generated income to pay maintenance cost, inverter replacement and also pay back the capital cost of the installation, however, if the incentive is to be lowered, then the payback period will be detrimentally affected. Evidently, this tariff drop has a larger impact upon the <4kWp systems, with an EPC below D, dropping from 21p per kWh to 9p per kWh. As a result the payback period is delayed further into the 25 year scheme.
<table>
<thead>
<tr>
<th>Property in conservation area</th>
<th>Total 25 year PV generation (kWh)</th>
<th>Total cost system, install and VAT</th>
<th>Income generation from feed in tariff</th>
<th>Total income over 25 years minus costs for 25 years of maintenance</th>
<th>Year payback occurs</th>
<th>Total income over 25 years minus costs for 25 years of maintenance</th>
<th>Year payback occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>58 Restalrig</td>
<td>No</td>
<td>190,648</td>
<td>£30,574</td>
<td>£54,239</td>
<td>12 to 13</td>
<td>£29,057</td>
<td>16 to 17</td>
</tr>
<tr>
<td>56 Restalrig</td>
<td>No</td>
<td>177,269</td>
<td>£31,560</td>
<td>£50,433</td>
<td>14 to 15</td>
<td>£27,017</td>
<td>17 to 18</td>
</tr>
<tr>
<td>74 Ferry Road</td>
<td>Yes</td>
<td>73,495</td>
<td>£13,930</td>
<td>£26,136</td>
<td>13 to 14</td>
<td>£11,201</td>
<td>21 to 22</td>
</tr>
<tr>
<td>1 Sandport way</td>
<td>Yes</td>
<td>57,840</td>
<td>£12,344</td>
<td>£24,510</td>
<td>15 to 16</td>
<td>£8,815</td>
<td>24 to 25</td>
</tr>
<tr>
<td>3 Sandport way</td>
<td>Yes</td>
<td>57,160</td>
<td>£12,344</td>
<td>£24,510</td>
<td>15 to 16</td>
<td>£8,815</td>
<td>24 to 25</td>
</tr>
<tr>
<td>5 Sandport Way</td>
<td>Yes</td>
<td>63,401</td>
<td>£12,406</td>
<td>£22,547</td>
<td>14</td>
<td>£9,663</td>
<td>22 to 23</td>
</tr>
<tr>
<td>9 Sandport Way</td>
<td>Yes</td>
<td>63,401</td>
<td>£12,406</td>
<td>£22,547</td>
<td>14</td>
<td>£9,663</td>
<td>22 to 23</td>
</tr>
<tr>
<td>17 Albert Street</td>
<td>No</td>
<td>178,151</td>
<td>£31,560</td>
<td>£50,433</td>
<td>13 to 14</td>
<td>£27,152</td>
<td>17 to 18</td>
</tr>
<tr>
<td>23 Jameson Place</td>
<td>Yes</td>
<td>188,919</td>
<td>£34,373</td>
<td>£53,747</td>
<td>13 to 14</td>
<td>£28,793</td>
<td>17 to 18</td>
</tr>
<tr>
<td>3 Academy Park</td>
<td>No</td>
<td>181,813</td>
<td>£29,085</td>
<td>£51,725</td>
<td>12 to 13</td>
<td>£27,710</td>
<td>16 to 16</td>
</tr>
<tr>
<td>34 Lorne Street</td>
<td>No</td>
<td>70,736</td>
<td>£13,185</td>
<td>£25,155</td>
<td>13 to 14</td>
<td>£10,781</td>
<td>22 to 23</td>
</tr>
</tbody>
</table>

Table 18 Summary of results for case study properties