# Solar PV An Assessment of the Household Characteristics, Utility and Potential of Photovoltaic Electricity Generation from Residential Property Rooftops in Northern Ireland



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# Solar PV

# An Assessment of the Household Characteristics, Utility and Potential of Photovoltaic Electricity Generation from Residential Property Rooftops in Northern Ireland.

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## Summary of Key Findings

### Current PV Installations and Households

a) There are 19,644 solar PV systems of 6.5Kilowatt capacity or less (likely to be residential) currently in Northern Ireland. This equates to 2.5% of the housing stock.[1]
b) In total, these 19,644 PV systems have a generation capacity of 79.6MWh.
c) Between 2013 and 2016 the number of PV systems installed in the province experienced rapid growth. In total, 91.6% of all PV installations were installed in the years 2013 to 2016 while the ROCs scheme, which provided financial incentives to households to install PV, was in operation.
d) The ending of the ROCs scheme in 2017, has halted new PV installations.
e) Households with PV installed typically have an annual reduction of 30% in electricity imported from the grid compared to pre-install electricity import consumption.
f) PV equipped households which have "Solar Plus" devices such as PV water heaters (costing £300) benefit from zero carbon hot water and export approximately 20% of generation to the electricity grid.
g) PV households without "Solar Plus" PV water heaters export 70% of generated electricity to the grid.
h) Current PV system owners in Northern Ireland can be characterised as predominantly living in rural areas, owner occupiers, with high educational attainment and are in the third and fourth least disadvantaged quintiles of the NISRA Multiple Deprivation Measure.

### The Potential for PV Generation

i) There are 821,250 dwelling and 426,858 domestic garage building polygons in the OSNI database of the province with a rooftop area of 67,289,866m$^2$ (dwellings) and 13,115,428m$^2$ (garages) totalling 80,405,294m$^2$ (80.4 Km2) of residential roof area.
j) With a roof availability figure of 35% for Solar PV, the assessed residential (dwellings and garages) potential annual generation for the province is 4,401 GWh.
k) In 2016-17 domestic electricity consumption in the province was 2907 GWh (DfE, 2020, P39), with a monthly average consumption of 242 GWh. Rooftop Domestic Solar PV has the potential to generate significantly more than this demand on an annual basis and exceed monthly demand for the months March to October.

[1] based on 785,684 Built Dwellings, Pointer Database 2020 and PV data from OFGEM

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## 1.1 Background and Policy Context

One of the last pieces of legislation enacted by Theresa May's government in June 2019 was the introduction of The Climate Change Act 2008 (2050 Target Amendment) Order 2019. This Order set a target for the net UK carbon account for the year 2050 to be 100% lower than the 1990 baseline, changing the Climate Change Acts initial 80% reduction goal, this new target has become known as "net zero carbon".

The UK has under 29 years to achieve this net zero objective, which amounts to an 87% reduction in $CO_2$ emissions compared to 2017 levels. Its attainment will necessitate societal, behavioural and technological changes, in the ways and extent to which we generate and consume energy. The Committee for Climate Change report, that in part prompted the adoption of the Net Zero target, foresees the "*extensive electrification, particularly of transport and heating, supported by a major expansion of renewable and other low-carbon power generation"* (Committee on Climate Change, 2019:23). This decarbonization process will necessitate the increasing use of renewable energy sources as a means of achieving these targets. A component of this is likely to be an extension of renewable energy production away from largely centralised electricity generation and towards home energy production and consumption.

Solar Photovoltaic (PV) is a mature technology and its adoption has increased dramatically in the last decade while the price of domestic PV systems has halved over the same period. A PV 4 kWp system now costs approximately £5,000, because of this and its comparative ease of installation, solar PV is very likely to have a role in achieving the Net Zero target.

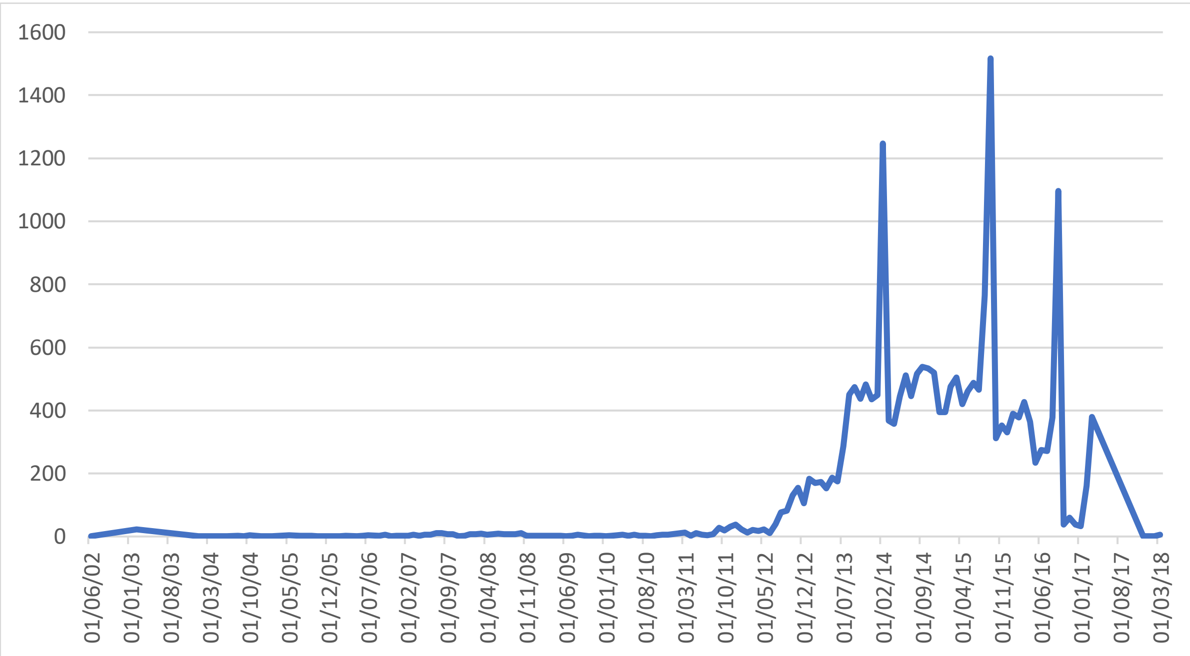
Solar Photovoltaic (PV) panels operate by converting solar radiation into electricity. *"Photovoltaic systems contain cells that convert sun-light into electricity. Inside each cell there are layers of a semi-conducting material. Light falling on the cell creates an electric field across the layers, causing electricity to flow. The intensity of the light determines the amount of electrical power each cell generates"* (Tyagi et al., 2013:444). PV installations can be large scale "solar farms" producing megawatts of electricity but the technology is also suitable for installation on domestic rooftops.

## 2.0 Characterisation of Current PV Installations in Northern Ireland

**PV Installation Quantification:**

This research utilised a comprehensive data set of PV installations in Northern Ireland provided by OFGEM and incomplete PV data provided by Northern Ireland Electricity Network (NIEN) and the NI Housing Executive (NIHE). The OFGEM data set contained details of 22229 PV installations.  The PV installations ranged in size from 0.4 to 49,500 kWp capacity. The average capacity was 14.5Kw and the median system size was 4Kw. The data contained complete details of PV size and installation date, commencing in 2002, of 22,207 PV systems and spatial data at Super Output Area (SOA) details for 22,084 installations. In the 19,644 PV installations assessed as to be residential (6.5 Kw or less) the median system size was 4Kw. Figure 1 below indicates several peaks in the numbers of installations in 2013, 2015 and 2016 and then a rapid decline in PV installations after 2017.

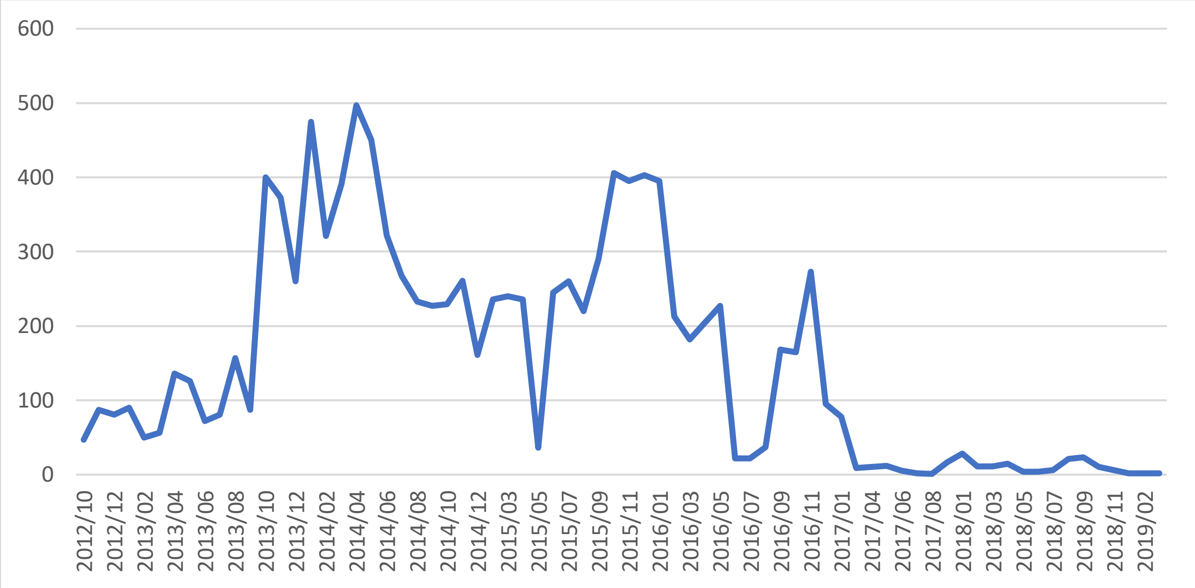
**Figure 1 Number of PV System Installations by Date**




**Source: OFGEM Data**

Further analysis of data provided by NIEN and the NIHE contained details of 13,476 PV installations including installation date information from 2012. As can be seen in Figure 2, a similar pattern of high installation numbers is evident with peaks notable in 2013, early 2014 late 2015 and late 2016 followed by a steep decline in the numbers of system installs post 2017.

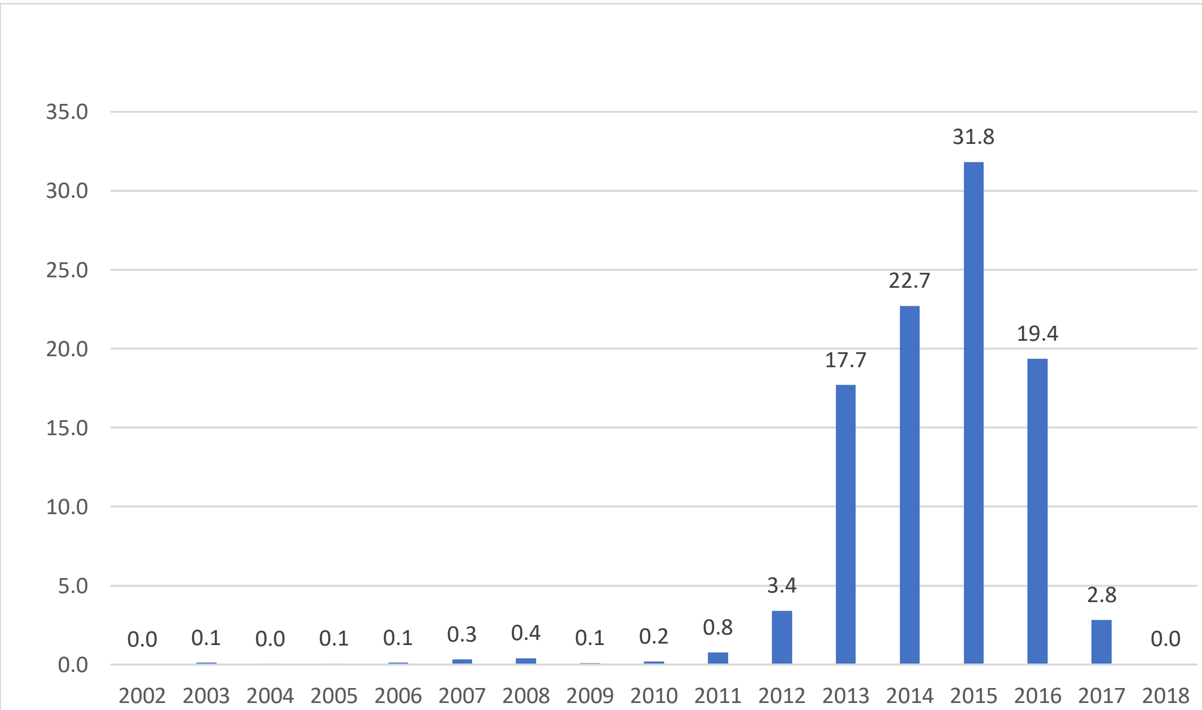
**Figure 2 PV Installations by Date**




**Source: NIEN Data**

Analysis of the OFGEM data to produce a percentage of total PV system installations in the province by year produced the following results. In 2012, there were 696 PV installations, with 2013 observing 3,607 installations. In 2015, the number of installations increased to 6,485, representing an uplift of 832% from 2012 levels. In 2017, there were 576 installations – equating to a decline in PV uptake from 2015 levels of 704%. Overall, 91.6% of all PV systems in the province were installed in the years 2013 to 2016.

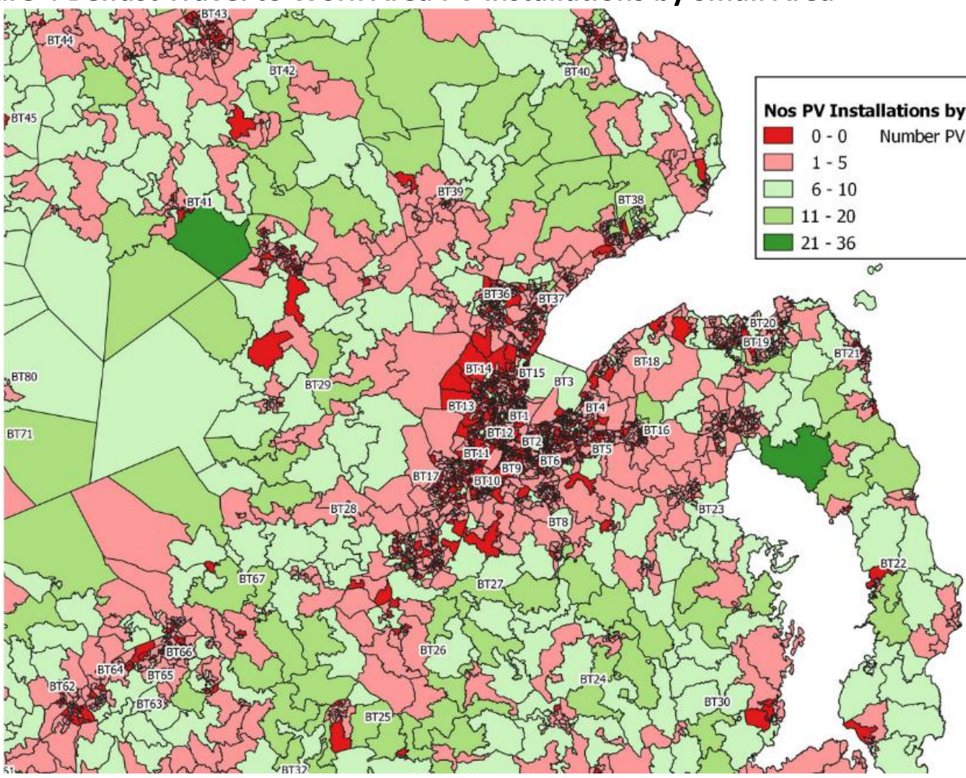
**Figure 3 Percentage PV Installations by Year**



### 2.1 Location of Solar PV Installations

Analysis of both the NIEN Small Area (SA) PV and OFGEM SOA data was undertaken. THE SA level data was incomplete however has a higher geographical resolution, with the SOA level data being complete in terms of the number of PV installations, but was at a lower geographical resolution. Initial analysis of the NIEN SA data and NIHE data recorded 13,476 PV installations. Of the 4,537 SAs in the province, 1,170 did not contain any PV installations identified from the NIEN data set. Figure 3 below shows the distribution of PV installation at SA level for the Belfast Travel to Work Area (depicting approximately the East of the province from Ballymena to Downpatrick). As can be seen there are significantly lower numbers of PV installations within the Belfast conurbation.

**Figure 4 Belfast Travel to Work Area PV installations by Small Area**




Analysis of the OFGEM PV data at Super Output Area (SOA) level reported 22,089 PV installations and established the following spatial distribution across the province:

- Out of the 890 SOAs, all except four SOAs contained PV installations.
- The average number of PV installations by SOA was 25 and;
- the highest number of PV installations in a single SOA was 179.

In broad terms, urban areas, especially in the east of the province, tend to have lower PV installation rates compared to rural SOAs in the south and west of the province (See Figure 5) In addition, a significant number of SOAs within Belfast and its surrounding conurbation either have no, or very few, PV installations (Figure 6).

**Figure 5 Number of Residential PV installations by SOA**

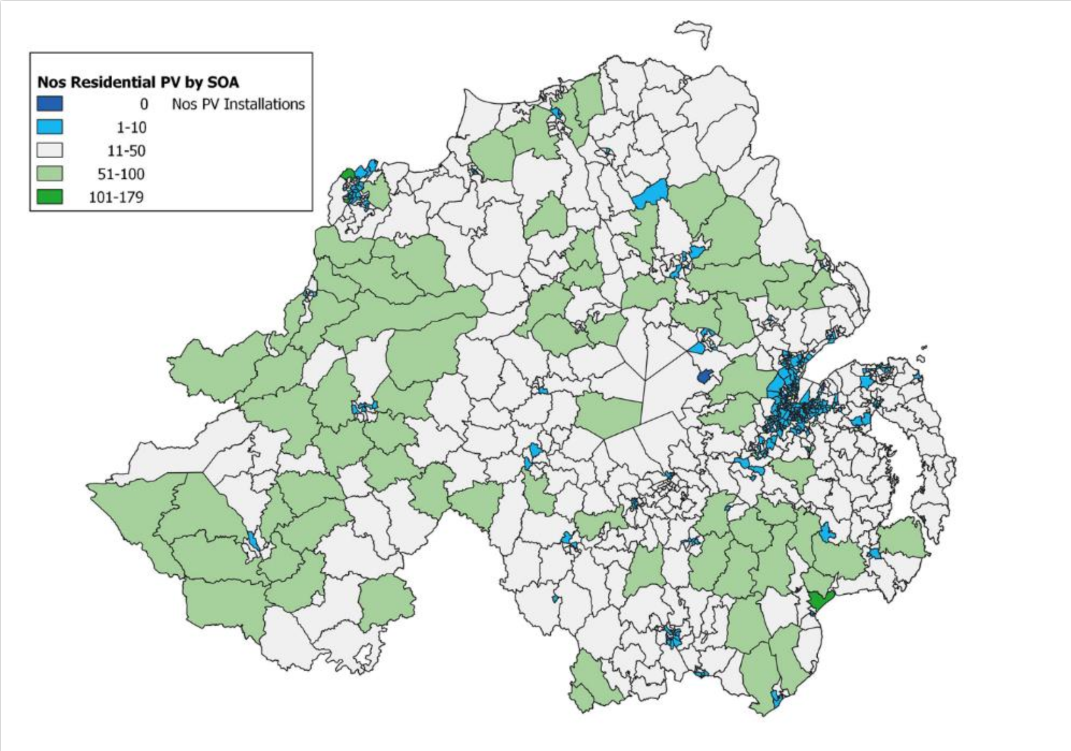
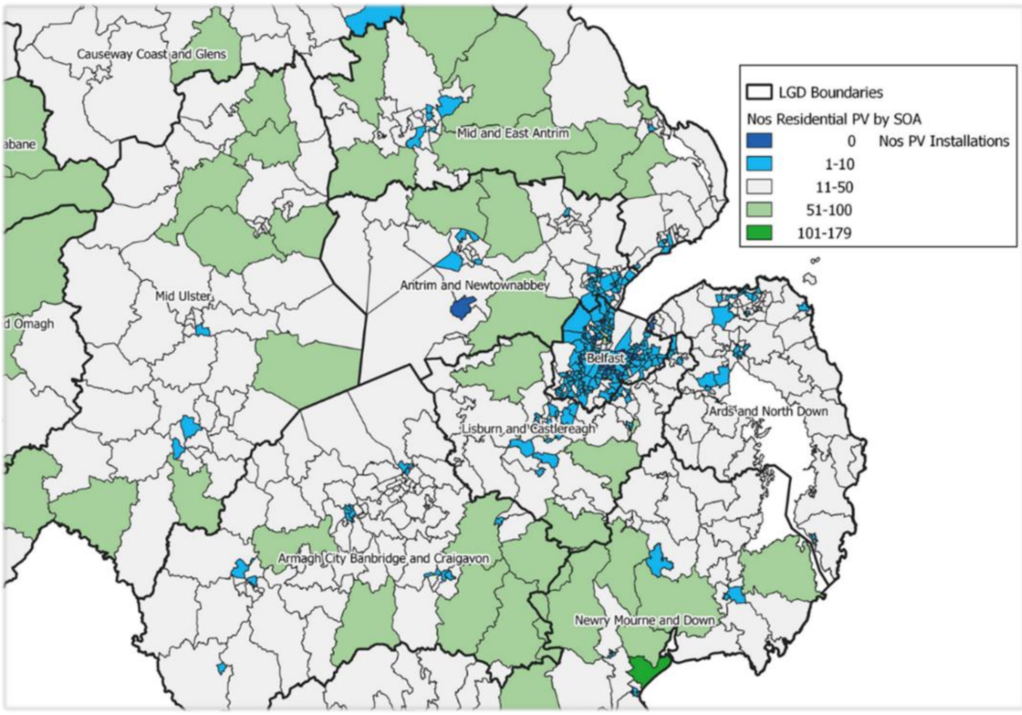



**Figure 6 Belfast and surrounding area residential PV installations by SOA**

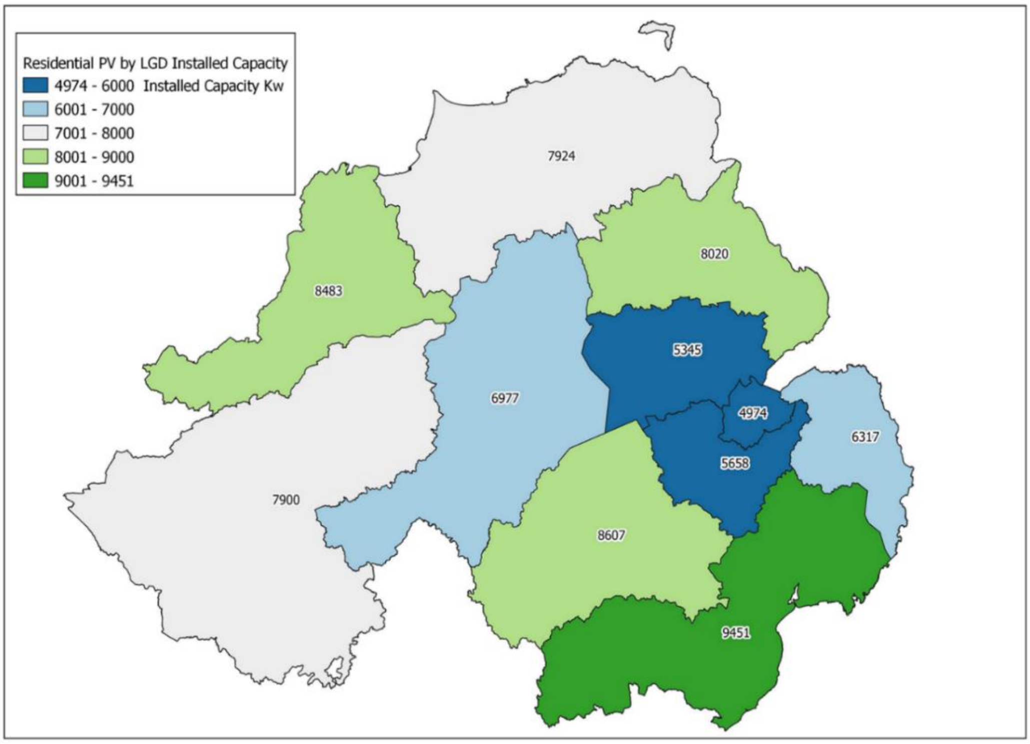



When the OFGEM residential PV data was mapped at Local Government District (LGD) level, as observed in Table 1 and Figure 7, the comparatively low levels of PV installations in the Belfast Metropolitan Area, North Down and Mid and South Antrim become apparent. This distribution is similarly reflected in the PV installed kWp capacity, with Newry and Mourne DC emerging as the LDG with the highest capacity.

**Table 1 Residential PV data was mapped at Local Government District level**

| LGD NAME | Res PV Nos by LGD | Percentage PV by LGD | Total Res PV kWp Installed by LGD |
|---|---|---|---|
| Belfast | 1185 | 6.0 | 4974 |
| Antrim and Newtownabbey | 1334 | 6.8 | 5345 |
| Lisburn and Castlereagh | 1425 | 7.2 | 5658 |
| Ards and North Down | 1641 | 8.3 | 6317 |
| Mid and East Antrim | 1730 | 8.8 | 8020 |
| Causeway Coast and Glens | 1886 | 9.6 | 7924 |
| Mid Ulster | 1974 | 10.0 | 6977 |
| Derry City and Strabane | 1989 | 10.1 | 8483 |
| Fermanagh and Omagh | 2019 | 10.3 | 7900 |
| Armagh City Banbridge and Craigavon | 2195 | 11.2 | 8607 |
| Newry Mourne and Down | 2302 | 11.7 | 9451 |
| Total | 19680 | 100.0 | 79656 |

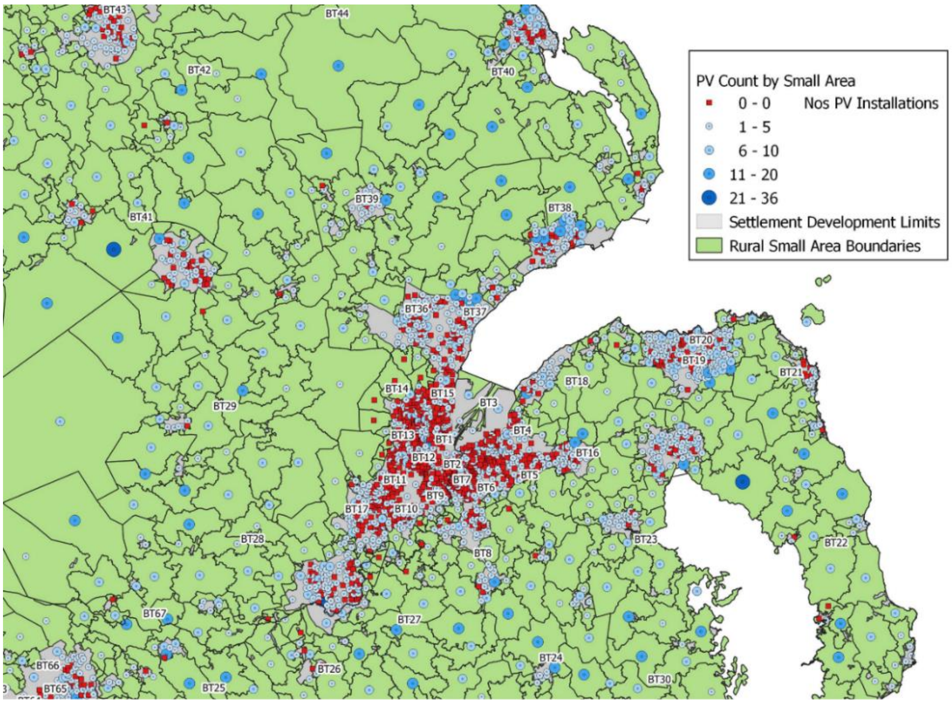
**Figure 7 Residential PV Installed Capacity kWp at Local Government District level**




## 2.2 Urban Rural Distribution of Solar PV at Small Area Level

The NIEN data was mapped at SA level and then analysed to determine if its location was urban or rural in character. This was achieved by layering the PV data against the Settlement Development Limits data set available from NISRA. As the settlement development limits and SA boundaries are not co-terminus, the PV SA data had to be converted to centroids (dots as opposed to polygons) to facilitate the best fit between the data sets. Figure 8 illustrates the PV installation count by SA across the urban-rural boundaries for Belfast Metropolitan Area (BMA).

**Figure 8 PV Installation count by SA across the urban-rural boundaries for BMA**



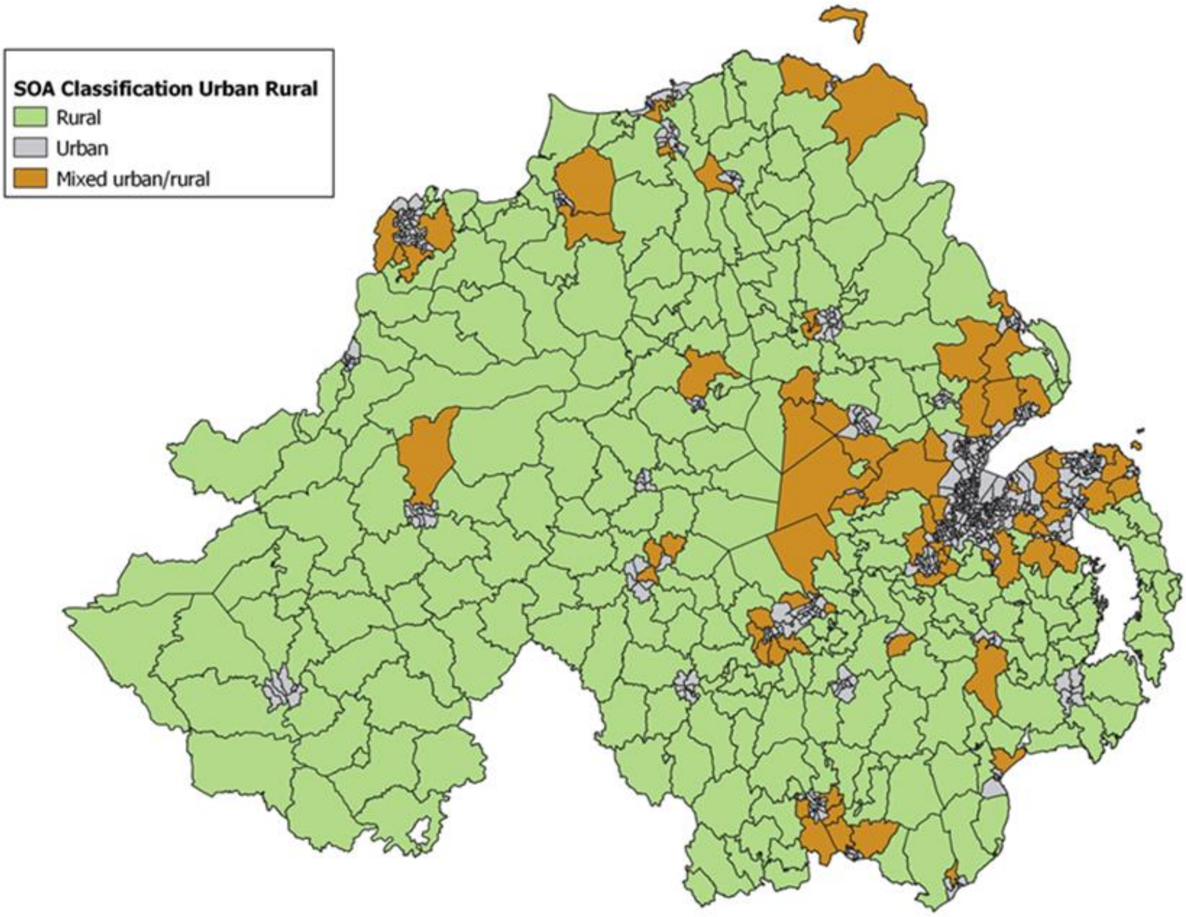

As can be seen, there is a marked correlation between those SAs with zero PV installations and an 'urban setting'. When the spatial distribution of the SA level data was examined in relation to its urban/rural location, the analysis (Table 2) shows that two thirds of the PV installations in this SA data set are located within rural areas, leaving one third as urban.

**Table 2 PV installations in urban-rural classification**

| | Nos PV SA Installations | % of PV SA Installations |
|---|---|---|
| Rural | 8,961 | 66.5 |
| Urban | 4,515 | 33.5 |
| Total | 13,476 | 100.0 |

There was the potential, as the PV Small Area data only contained 61% of the known 22,000 PV installations, that this urban rural split was an artefact of which organisation the PV systems had been registered to and not their actual spatial distribution. In order to verify the urban/rural spatial distribution, the same analysis was undertaken as far as practicably achievable with the OFGEM SOA data set. SOA boundaries and development limits are not co-terminus, in many cases SOA boundaries stray over the settlement development limits. NISRA has, because of this, introduced an intermediate category of "Mixed; Urban; Rural" to categorise these SOAs. Figure 8 illustrates the urban rural distribution of SOAs. An example of a "mixed urban rural" would be the SOA containing Ballynure which is classified as a "Hamlet". While classified as "mixed" the majority of the SOA is in fact rural with only a small portion containing the settlement. The character of these "mixed" areas can therefore be viewed as predominantly rural.

**Figure 9 Classification of Urban, Mixed and Rural**




These NISRA urban, rural and mixed classifications revealed the following distribution of PV installations in urban, rural or mixed locations (Figure 10 and Figure 11).

**Figure 10 Residential PV installations at SOA level for Urban, Mixed and Rural categories**

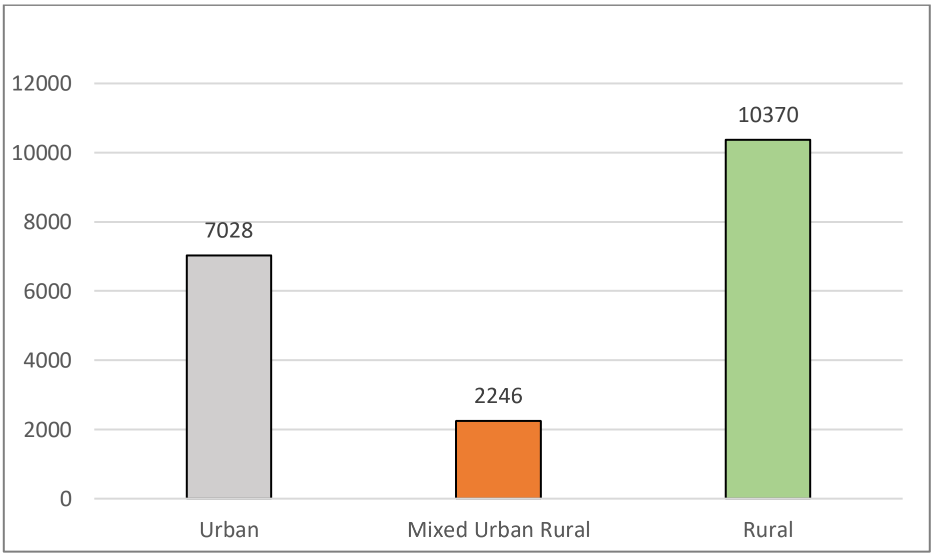
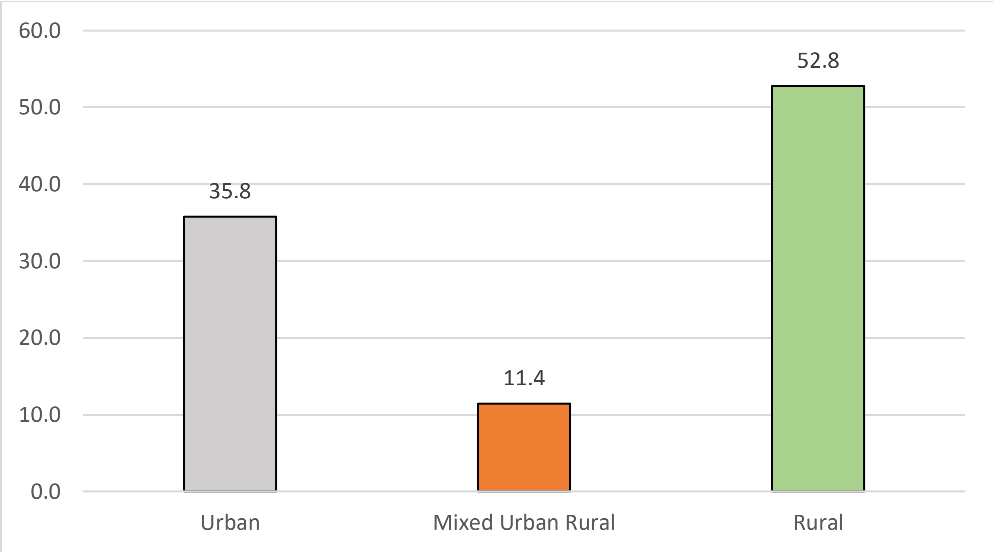


**Figure 11 Residential PV percentages at SOA level for Urban, Mixed and Rural categories**




Further manipulation of the classifications indicates that when 'mixed' is classified as 'rural', the percentage split between the urban and rural PV installation is a one third urban to two thirds rural for both the OFGEM and NIEN data sets (Table 3).

**Table 3 Altered Urban-Rural classifications**

| | Nos PV SA Installations | % of PV SA Installations | | Nos PV SOA Installations | % PV SOA Installations |
|---|---|---|---|---|---|
| Rural | 8,961 | 66.5 | Rural/Mixed | 12,616 | 64.2 |
| Urban | 4,515 | 33.5 | Urban | 7,028 | 35.8 |
| Total | 13,476 | 100.0 | Total | 19,644 | 100.0 |

The results from the analysis of both the OFGEM and NIEN PV data sets indicates that approximately 67% of PV installations in the province are located outside settlement development limits - in rural areas. There is also a marked difference in installation rates between Local Authorities in the Greater Belfast Area than the remainder of the province.

### 2.3 Solar PV User Characterisation:

#### 2.3.1 The Relationship between the Distribution of PV Installations and Deprivation

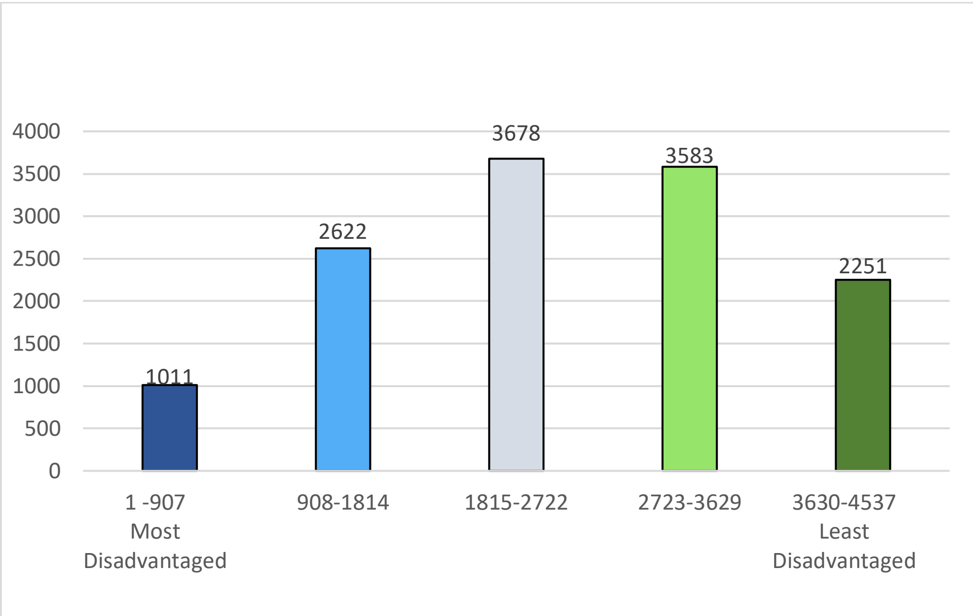
The research objective was to assess the location of PV installations against the Northern Ireland Statistical Research Agency (NISRA) Multiple Deprivation Measures (MDM) and some of its constituent domains such as Income and Education. The NISRA MDM data ranks these measures at various geographies with 1 being the most disadvantaged, for Small Areas (SA) the least disadvantaged is ranked at 4,537 and for super Output Areas (SOA) the least disadvantaged is ranked at 890. The Small Area data from NIEN was linked to the NISRA

Multiple Deprivation Measure to determine how many PV installations fall with each quintile of the of the MDM rankings. The results as displayed in Table 4 and the Figure 12 below, indicates that the majority of PV installations are located within the SAs that are ranked in the third and fourth least disadvantaged quintiles with each containing 27% to 28% of installations. The first quintile (Most Disadvantaged) has substantially lower levels of PV uptake at 7.7% than the others.

**Table 4 PV installations by SA Deprivation Rank**

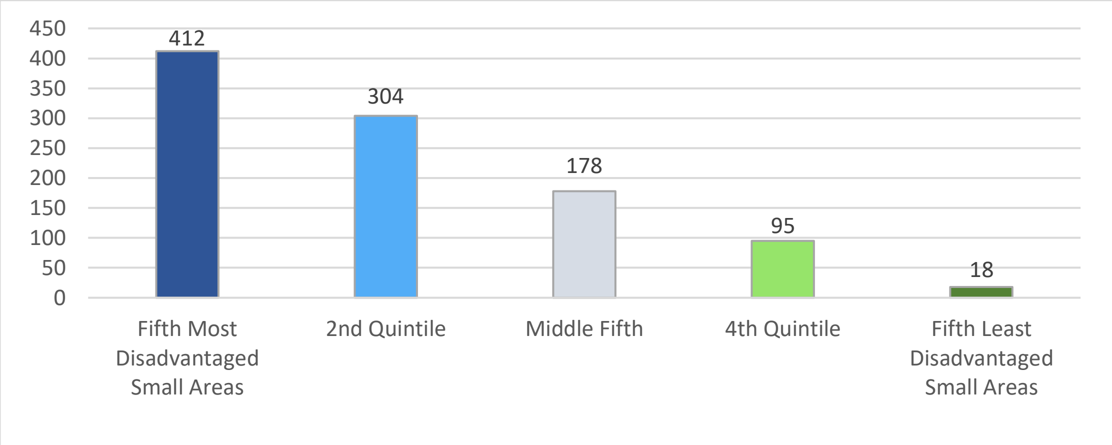
| Small Area MDM Rank | Nos PV Installations | Mean by SA | Percentage by Quintile |
|---|---|---|---|
| 1 -907 Most Disadvantaged | 1011 | 1.1 | 7.7 |
| 908-1814 | 2622 | 2.9 | 19.9 |
| 1815-2722 | 3678 | 4.1 | 28.0 |
| 2723-3629 | 3583 | 4.0 | 27.3 |
| 3630-4537 Least Disadvantaged | 2251 | 2.5 | 17.1 |
| Total | 13145 | | 100.0 |

**Figure 12 PV Installations by Small Area Multiple Derivation Measure**




In addition, the data provided by the NIHE in relation to PV Installations on their housing stock shows that 70% of its installations are concentrated in the first and second most disadvantaged quintiles (Figure 13).

**Figure 13 NIHE PV Installations Per Census Small Area Multiple Deprivation Measure**

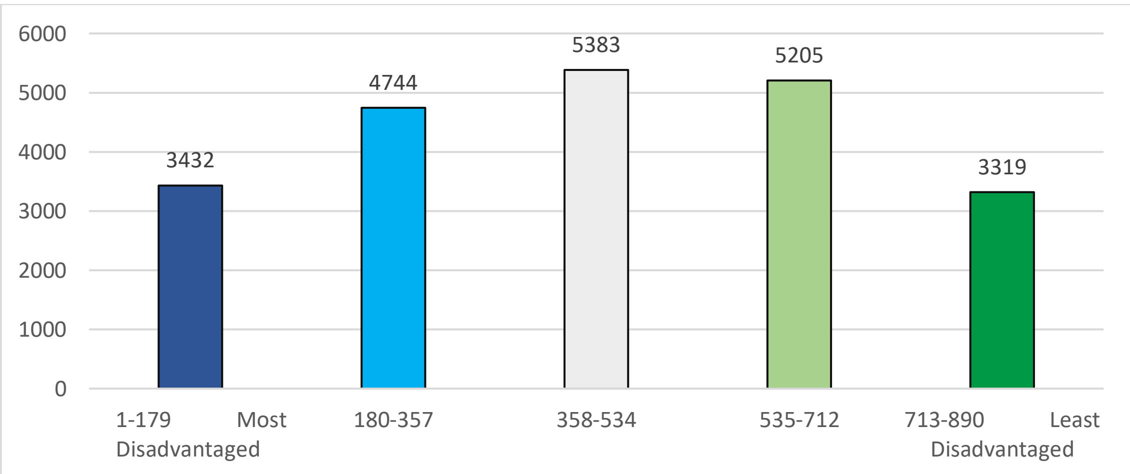



When the OFGEM data for the total number of PV Installations is examined at SOA level, the discrepancies between the SA data and the SOA data becomes apparent. The first quintile in the SA data shows significantly lower PV representation than the SOA data. Table 5 and Figure 14 below illustrate the distribution of the total number (22,083) PV system installations in the province across the MDM quintiles.

**Table 5 PV installations and SOA MDM Ranking**

| SOA MDM Ranking | Nos PV | Mean Nos PV by SOA | % by Quintile |
|---|---|---|---|
| 1-179 Most Disadvantaged | 3432 | 19 | 15.5 |
| 180-357 | 4744 | 28 | 21.5 |
| 358-534 | 5383 | 30 | 24.4 |
| 535-712 | 5205 | 29 | 23.6 |
| 713-890 Least Disadvantaged | 3319 | 19 | 15.0 |
| Total | 22083 | | 100.0 |

**Figure 14 PV installations by SOA MDM**



When the 19,644 PV installations of a system size of 6.5 Kilowatts or less (assessed as residential) are examined, the results are in line with the total PV distribution. Again, the analysis shows the third and fourth quintiles to have the highest proportion of PV installations.

**Table 6 PV distribution with SOA MDM Ranking**

| SOA MDM Ranking | Nos Res PV | Mean by SOA | Percentage by Quintile |
|---|---|---|---|
| 1-179 Most Disadvantaged | 2969 | 16.6 | 15.1 |
| 180-357 | 4180 | 23.5 | 21.3 |
| 358-534 | 4822 | 27.2 | 24.5 |
| 535-712 | 4676 | 26.3 | 23.8 |
| 713-890 Least Disadvantaged | 2997 | 16.8 | 15.3 |
| | 19644 | | 100.0 |

The residential PV installations broadly follow a Gaussian distribution curve across the MDM rankings, with the number of PV installations in the first and fifth quintiles being symmetrical.

**Figure 15 Residential PV by SOA MDM Quintiles**

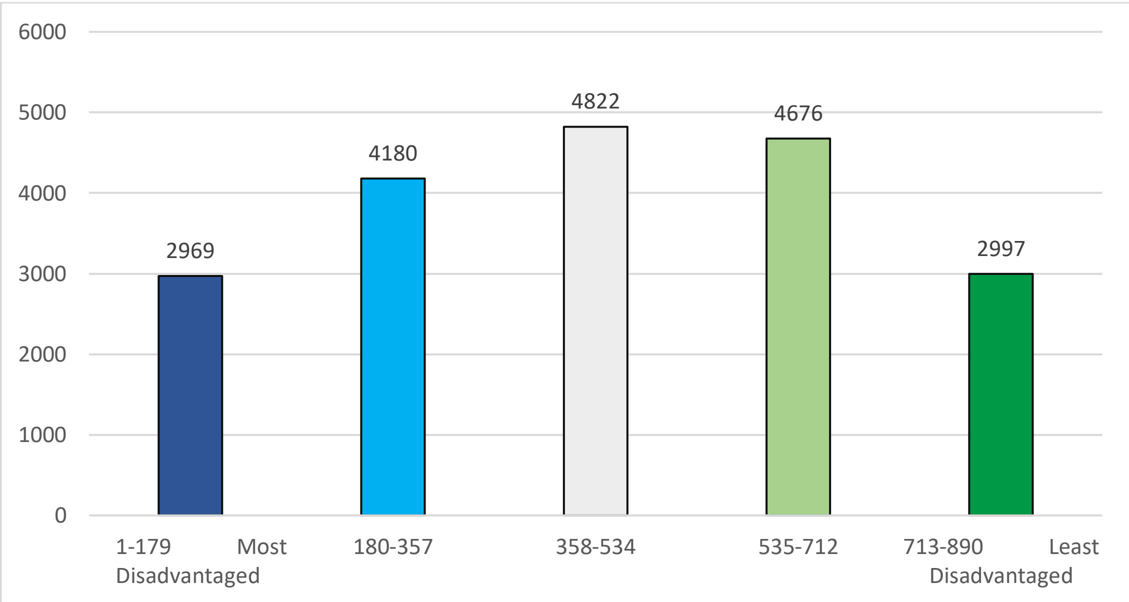
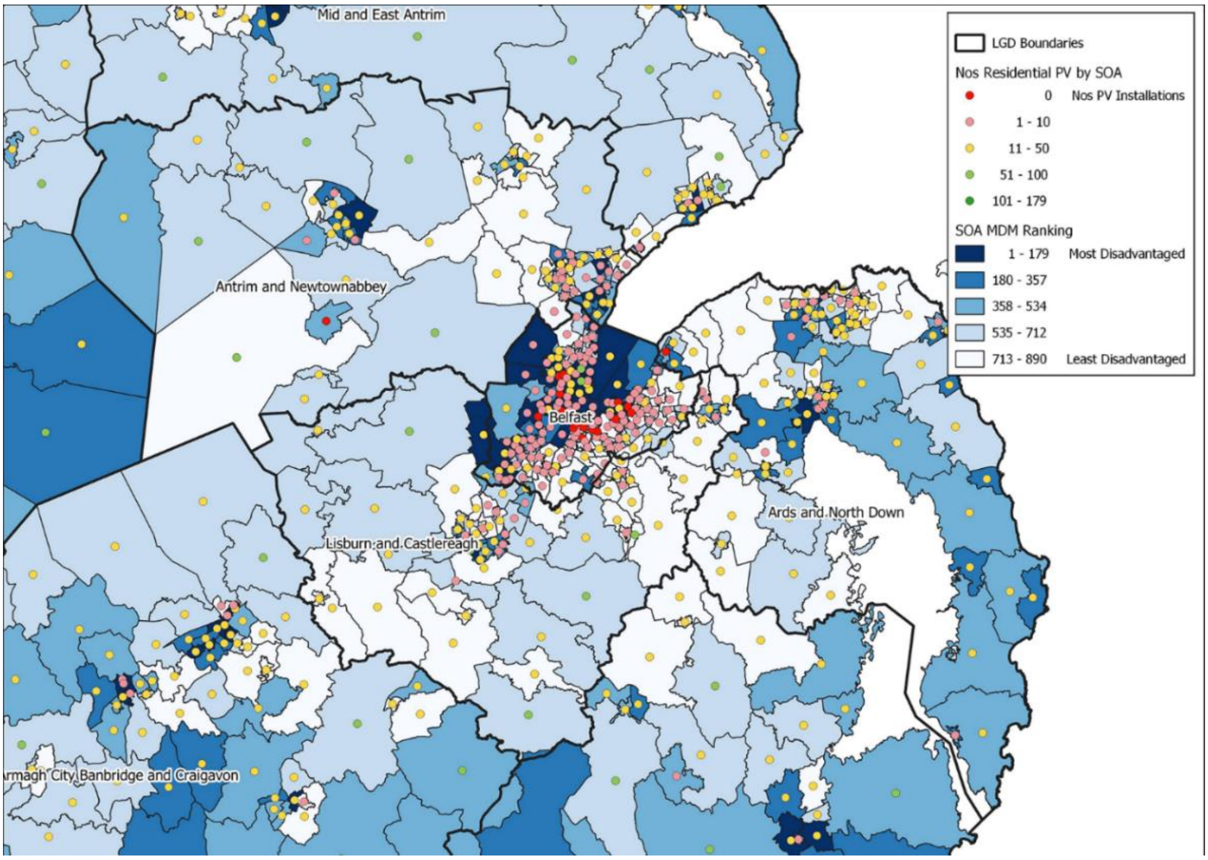



Figure 16 illustrates the distribution of residential PV installations by SOA across the Belfast Metropolitan Area overlaid on top of the NISRA MDM data. As can be seen there is a concentration of SOAs either with no PV or 10 or less PV installations within the most disadvantaged areas of Belfast. Those SOAs with higher numbers of PV installations tend to be in the surrounding rural areas.

**Figure 16 PV installations by SOA across the BMA**



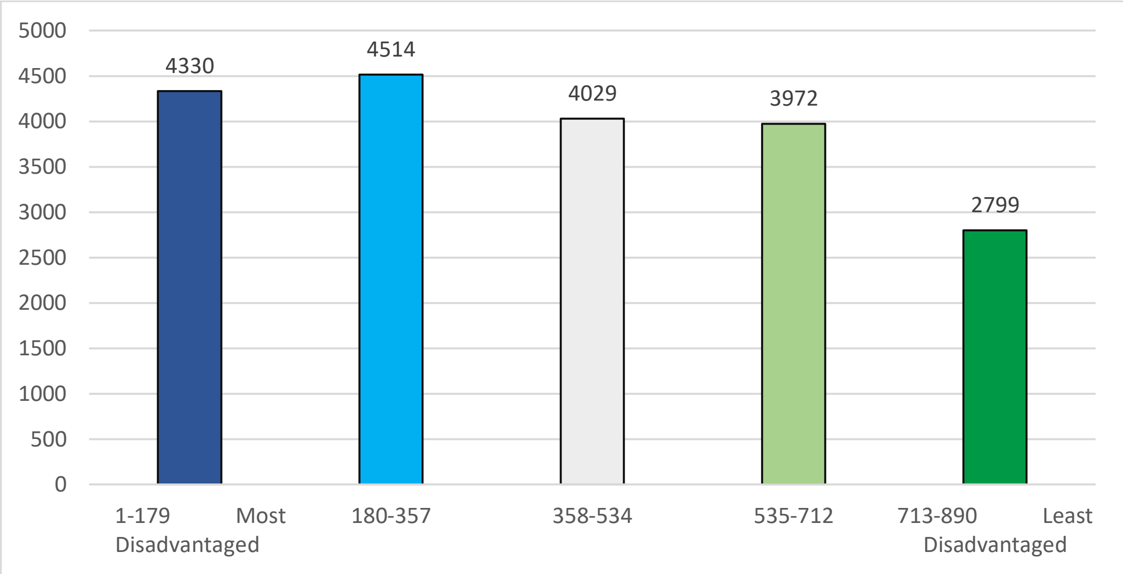

## 2.3.2 The Relationship between the Distribution of PV Installations and Income

The MDM Income domain was isolated for specific analysis to determine the number of PV installations by Income quintiles. The results below exhibit a fairly even distribution of PV installations (Table 7) between the first four quintiles with only the fifth quintile having a markedly lower number of installations. The analysis highlights the lower prevalence of PV installations within the highest Income quintile (Figure 17).

**Table 7 PV distribution and MDM Income Ranking**

| SOA Income Ranking | Nos Res PV | Mean by SOA | Percentage by Quintile |
|---|---|---|---|
| 1-179 Most Disadvantaged | 4330 | 24.2 | 22.0 |
| 180-357 | 4514 | 25.4 | 23.0 |
| 358-534 | 4029 | 22.8 | 20.5 |
| 535-712 | 3972 | 22.3 | 20.2 |
| 713-890 Least Disadvantaged | 2799 | 15.7 | 14.2 |
| | 19644 | | 100.0 |

**Figure 17 PV distribution and MDM Income Ranking**



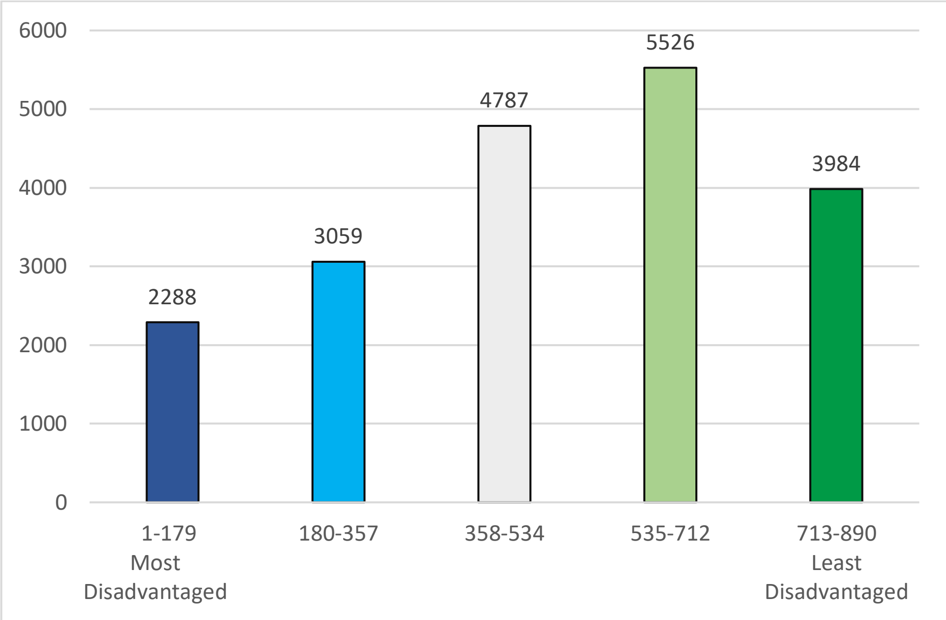

### 2.3.3 The Relationship between the Distribution of PV Installations and Educational Attainment

The MDM Education domain was isolated for specific analysis to determine the number of PV installation by Educational attainment quintiles. The results below show a that the prevalence of PV installations is highest amongst the third and four quintiles, with the first quintile having a markedly lower number of installations. As evidenced in Table 9 and Figure 18, the lower prevalence of PV installations falls within the quintile with the lowest Educational attainment.

**Table 9 PV installations by SOA Education Deprivation Ranking**

| SOA Education Ranking | Nos Res PV | Mean by SOA | % by Quintile |
|---|---|---|---|
| 1-179 Most Disadvantaged | 2,288 | 12.8 | 11.6 |
| 180-357 | 3,059 | 17.2 | 15.6 |
| 358-534 | 4,787 | 27 | 24.4 |
| 535-712 | 5,526 | 31 | 28.1 |
| 713-890 Least Disadvantaged | 3,984 | 22.4 | 20.3 |
| Total | 19,644 | | 100.0 |

**Figure 18 Residential PV installations by SOA Education Domain Quintiles**




## 2.3.4 The Relationship between the Distribution of PV Installations and Housing Tenure

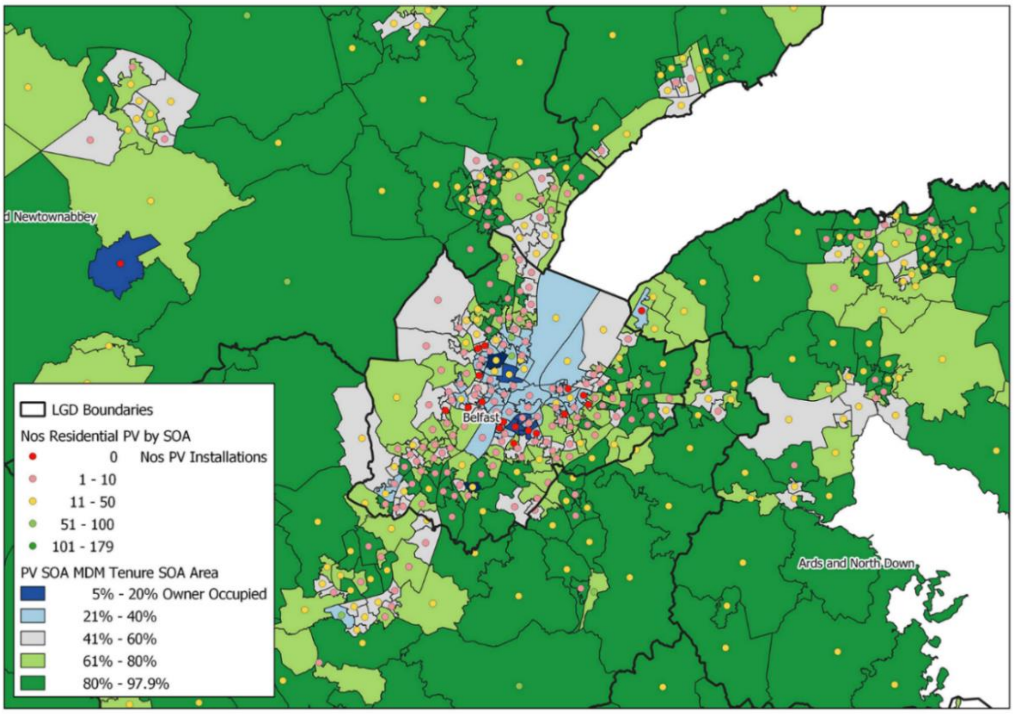
Data on the type of tenure, Owner Occupied, Social and Private Rented by SOA was obtained from NISRA and joined to the PV by SOA data set. Each type of tenure (Owner Occupied, Social and Private Rented) was sorted by percentage quintile bands by SOA and the prevalence PV installations obtained for each tenure type and percentage band (Table 10).

**Table 10 Tenure composition by SOA**

| Percentage Tenure by SOA | Owner Occupied Nos PV | Social Rented Nos PV | Private Rented Nos PV |
|---|---|---|---|
| 80-100% | 8277 | | |
| 60-79% | 7925 | 161 | 12 |
| 40-59% | 2608 | 861 | 15 |
| 20-39% | 815 | 1900 | 2677 |
| 1-19% | 19 | 16722 | 16940 |
| Total | 19644 | 19644 | 19644 |

The results indicate that PV installations are concentrated in those SOAs with the highest percentages of Owner-Occupied households. Conversely those SOAs with the highest percentages of Social and especially Private Rented households have relatively few PV installations (Figure 19).

**Figure 19 PV Installations and MDM tenure**



## 3.0 Assessing the Potential Rooftop Generation of Residential PV in Northern Ireland

Undertaking this assessment utilised a combination of GIS analysis, PV GIS system generation locational capacity information, PV panel sizes and assumptions on roof availability and pitch.

### 3.1 PV Potential Assessment Methodology Components

a) OSNI BaseMap data provided information on the area (footprint $m^2$) of residential buildings in the province.
b) OSNI Local Government District (LGD) Boundaries GIS data
c) European Commission, PV GIS Performance of Grid Connected ( https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP) Yearly PV energy production web tool
d) Appraisal of the Factors limiting rooftop generation
e) Assumptions on both the percentage of properties with pitched roofs and the angle of the pitch.
f) Details of PV Panel sizes.
g) Orientation of Residential Building Polygons GIS Plugins.

### 3.2 Spatial Analysis Methodologies

The analysis of the data was carried out using Geographical Information Software (GIS), with three different programs used: QGIS 3.4.15, Arcview 3.3 and ArcGIS 10.4.1. The three different programs were applied as each has a slightly different range of functions. This also facilitated comparisons to be made enabling the checking of results between the software packages.

The latest edition of Ordinance Survey for Northern Ireland (OSNI) BaseMap (2020) was obtained. BaseMap contains the vector data on all buildings in the province providing details of the "footprint" area of each dwelling in square metres and classifies the buildings as domestic, commercial, education, recreation use etc. (Figure 20). The Domestic building polygons were isolated from the BaseMap resulting in a dataset with a total of 825,351 residential polygons. This data was examined and small "sliver" polygons and small single feature dwelling house polygons of less than $12m^2$ purged from the database. This process left a total of 821,250 domestic dwelling polygons in the database. This data was subsequently joined with the LGD boundaries and a spatial dissolve carried out to determine the number of dwelling (house) polygons and their area in square metres determined within each Local Council.

In addition to the domestic building polygons for dwellings, a BaseMap polygon description of "Other Buildings General" was also appraised, as this contains information on domestic garages. However, in addition to domestic garages, this category also includes agricultural buildings, large sheds and outhouses. Therefore, a size limit had to be determined that would include domestic garages but would exclude these large non-residential "Other Buildings". An examination of residential areas with garages was undertaken using GIS and it was determined that having an upper limit area of $75m^2$ would capture almost all domestic garages but would exclude the non-residential sheds. Similarly, those buildings that were too small to accommodate a rooftop PV installation had to be identified. It was decided that roofs with an area of less that $12m^2$ would be excluded as this was the minimum size estimated to be the capable of accommodating a 1Kw PV installation.

There are 608,248 polygons in the BaseMap "General Buildings" database. These were examined by area and the polygons with areas of between $12m^2$ and $75m^2$ were selected. Polygons comprising only one feature i.e. not a split polygon and with areas less than $12m^2$ were deleted from the data base. This filtering process reduced the number of "General Building" polygons to 426,857 for analysis. The selected garage polygons were then joined with the LGD boundaries database to determine the number of these buildings within each Local Government District. Figure 21 also provides an example of the buildings selected by this data filtering process.

**Figure 20 BaseMap Building Types and Analysis Selection Criteria**

**Figure 21 Buildings Selected for Analysis**


### 3.3 Determining Proportion of Rooftop PV Installation Availability

Several factors limit the area of roofs that can be utilized for PV installations. These include the orientation of the roof, with South and West facing roofs being most favourable in the northern hemisphere; the design of the roof in terms of whether it is flat or pitched, together with the presence of roof lights or dormer windows which would restrict accommodating PV panels; the extent of shading of the roof by adjacent buildings and trees is also important factor limiting PV potential. Research undertaken by (Wiginton et al, 2010:352) examined the fraction of available roof area for PV installation across a range of determination methods and countries. Their results indicated that the fraction of roofs available for PV ranges from 0.22 to 0.95 with an average of 0.47[2]. Based on the Wiginton et al. (2010) research it was decided to run the Northern Ireland rooftop availability analysis of the BaseMap polygons based on seven fractions (0.22, 0.25, 0.3, 0.35, 0.4, 0.45 and 0.47) to provide a range of outputs from conservative to generous estimations of rooftop availability.

In relation to domestic properties in Northern Ireland, there is some information available on limiting factors. The 2016 House Condition Survey "estimated that 747,700 (96%) dwellings had lofts", (NIHE, 2016:79). If the dwellings have a loft, this can only be accommodated via the presence of a pitched roof. If roofs have a pitch this in turn denotes that only half of the roof area will be orientated to the south or west, the more favourable directions for PV Installations. Thus, the rooftop pitch and related orientation factor produce a reduction of 0.5

[2] See: Wiginton, L. K., Nguyen, H. T., & Pearce, J. M. (2010). Quantifying rooftop solar photovoltaic potential for regional renewable energy policy. *Computers, Environment and Urban Systems*, *34*(4), 345-357.

in roof PV availability. As the fraction of residential roofs in the province with a pitch is 96%, for the purpose of this analysis an assumption has been made that for all residential roofs PV availability is going to be 0.5 or below. This assumption is necessary, as it is not possible from the BaseMap databases to determine which dwellings or garages have pitched or flat roofs.

A further assumption is also required on the roof pitch as the area of a pitched roof will be greater than the area of the footprint of the building. In the UK a roof pitch between 25 degrees and 47.5 degrees would be considered conventional[3]. For the purpose of this study, a roof pitch of 35 degrees was selected as typical. Using a calculation of Cosine 35 degrees, this produced a multiplication factor of 1.2 for the building footprint area to roof area. Consequently, the dwelling polygon areas were multiplied by 1.2 to take account of this in the methodology.

**3.4 Typical Solar Panel Size, Area and Output.**

A figure had to be determined of a representative area and power output for individual solar panels. A review of PV solar panels by Which UK, which involved asking 1,978 solar PV owners about their systems, produced a ranking of the best rated manufacturer PV brands. The websites of the top 8 of these were appraised and details of panel dimensions and outputs noted (Table 11).

**Table 11 PV Brands and dimensions**

| Solar Panel | Width (m) | Height (m) | Power Wp | Area m2 |
|---|---|---|---|---|
| Suntech | 1.66 | 0.99 | 250 | 1.64 |
| Sanyo | 1.6 | 0.86 | 250 | 1.38 |
| Invensun | 1.63 | 0.99 | 250 | 1.61 |
| Hyundai | 1.96 | 0.99 | 250 | 1.94 |
| Canadian Solar | 1.64 | 0.98 | 250 | 1.61 |
| Sanyo | 1.60 | 0.86 | 250 | 1.38 |
| Panasonic | 1.58 | 0.798 | 250 | 1.26 |
| Romag | 1.63 | 0.99 | 250 | 1.61 |
| | | | Average | 1.55 |

In order to estimate the number of panels that could be accommodated on the dwelling roof areas, an average PV panel size of 1.6 $m^2$ and a generating capacity of 250Wp was chosen as being typical of those available currently on the market. This information was added to the dwelling polygon data to establish the number of 1.6$m^2$ panels that could be accommodated by the rooftop area and the output capacity of the panels. It should be noted that the generation output of PV panels is increasing, with 300 to 400 watt panels entering the market and projections that within two years 700 watt panels could be available.

[3] See: https://dwbgroup.co.uk/how-to-measure-the-pitch-angle-of-your-roof/

### 3.5 Building Orientation

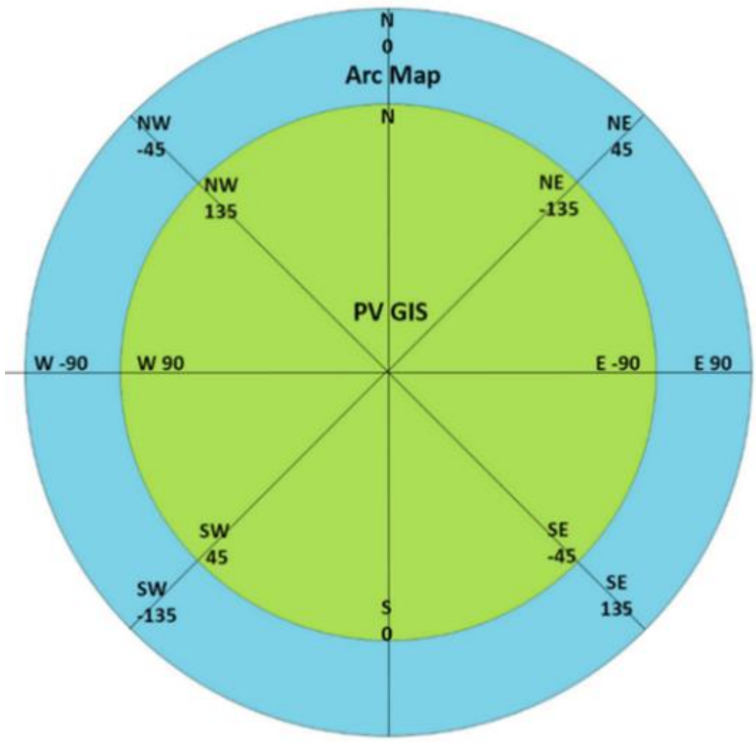
The orientation of buildings has a considerable impact on the amount of available solar radiation. As Table 12 illustrates, the variability dependant on orientation of solar radiation in kWh/m$^2$ falling on the centroid location for Mid-East Antrim Council. While there is only a 5% fall in solar irradiation levels between due South and 45 degrees East or west orientations, at 90 degrees East and West this becomes an 18% drop in levels.

**Table 12 orientation of solar radiation in kWh/m2 falling on the centroid location for Mid-East Antrim Council**

| Location | NE-135 | W 90 | West 45 | South 0 | East- 45 | NE -90 | N -135 |
|---|---|---|---|---|---|---|---|
| Centroid Mid East Antrim Solar Radiation kWh/m2 | 700.0 | 853.9 | 984.3 | 1030.2 | 972.4 | 839.9 | 692.1 |

To account for this variation, further spatial analysis was undertaken to determine the orientation relative to North of each of the 821,250 dwelling polygons and 426,858 garage polygons in QGIS around each polygon. This polygon assessment of spatial orientation was also undertaken using ArcMap GIS software. In ArcMap the angle is calculated clockwise with 0 at North, while with the PV GIS modelling tool South is 0. However, as all roofs were assumed to be pitched, and only half of the roof would be used in the PV capacity appraisal, this meant that a roof assessed in ArcMap at angle -20 (North-West) the favourable half of the roof is directly opposed which equals -20 (South-East) in the PV GIS modelling (See below Figure 22). Therefore, the ArcMap orientation figures were inputted directly into the PV GIS modelling tool outputs without further conversion

**Figure 22 ArcMap and PVGIS Orientation**



This orientation data was added to the dwelling polygon attribute table for each individual polygon and the same process was repeated for the residential garage polygons (Figure 23).

**Figure 23 Dwellings with Orientation Details**


### 3.6 Location and Solar Irradiation

The amount of solar radiation varies by location on the earth's surface. To account for this variation within Northern Ireland, the centroid locations for each of the eleven District Council Areas in the province were calculated using GIS and the Latitude and Longitude entered into the EU PV GIS modelling web application (Figure 24).

The variation of yearly energy production for the eleven locations across the province, and at a range of orientation angles was then modelled using the EU PV GIS web tool. The modelling was based on a 4Kw PV system with pitched roof dwelling at an angle of 35 degrees and the percentage output from each location and building orientation calculated (See Table 13).

**Figure 24 Northern Ireland LGD Centroids**

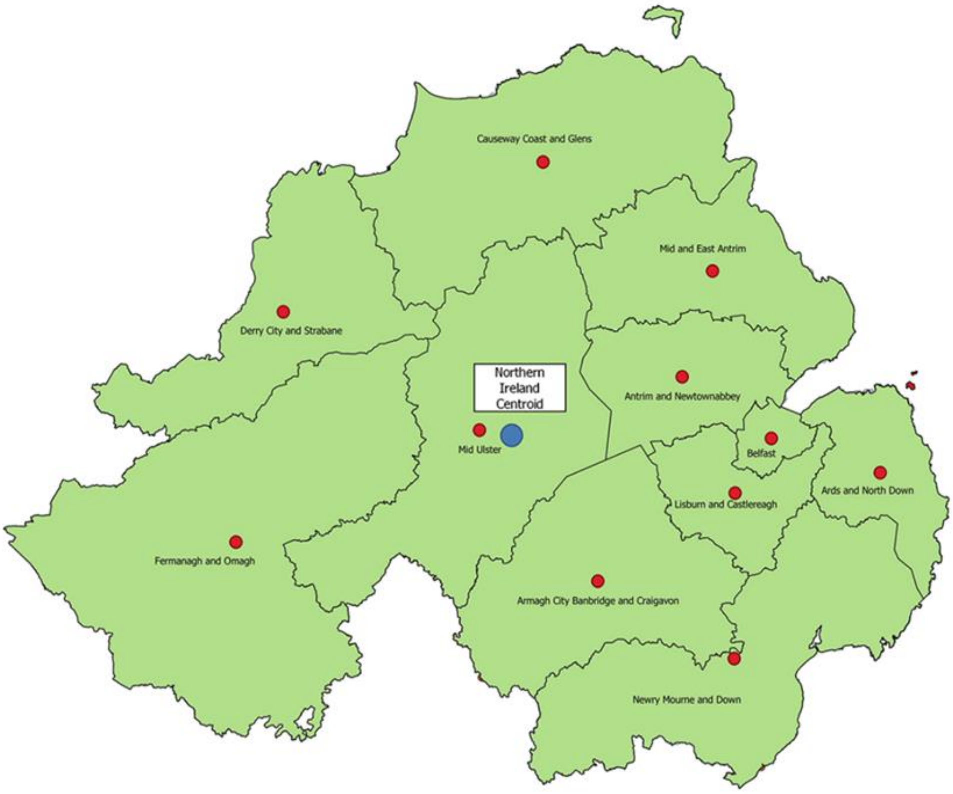



**Table 13 PV GIS Yearly PV Output from a 4 kWh PV System by Northern Ireland LGD**

| Local Government District (LGD) | West 90 | SW 45 | South 0 | SE - 45 | East - 90 |
|---|---|---|---|---|---|
| Antrim and Newtownabbey | 2746.9 | 3233.8 | 3424.2 | 3231.7 | 2748.6 |
| *PV GIS % Output of 4Kw System* | 68.7 | 80.8 | 85.6 | 80.8 | 68.7 |
| Ards and North Down | 2903.1 | 3476.8 | 3705.7 | 3472.5 | 2897.7 |
| *PV GIS % Output of 4Kw System* | 72.6 | 86.9 | 92.6 | 86.8 | 72.4 |
| Armagh City Banbridge and Craigavon | 2796.1 | 3321.4 | 3540.9 | 3344.8 | 2828.8 |
| *PV GIS % Output of 4Kw System* | 69.9 | 83.0 | 88.5 | 83.6 | 70.7 |
| Belfast | 2811.4 | 3344.1 | 3562.5 | 3357.1 | 2832.5 |
| *PV GIS % Output of 4Kw System* | 70.3 | 83.6 | 89.1 | 83.9 | 70.8 |
| Causeway Coast and Glens | 2648.4 | 3110.4 | 3294.3 | 3113.1 | 2654.0 |
| *PV GIS % Output of 4Kw System* | 66.2 | 77.8 | 82.4 | 77.8 | 66.3 |
| Derry City and Strabane | 2570.9 | 2999.6 | 3169.7 | 3004.5 | 2588.9 |
| *PV GIS % Output of 4Kw System* | 64.3 | 75.0 | 79.2 | 75.1 | 64.7 |
| Fermanagh and Omagh | 2658.6 | 3114.1 | 3300.4 | 3125.2 | 2678.7 |
| *PV GIS % Output of 4Kw System* | 66.5 | 77.9 | 82.5 | 78.1 | 67.0 |
| Lisburn and Castlereagh | 2773.2 | 3287.7 | 3502.4 | 3309.9 | 2803.2 |
| *PV GIS % Output of 4Kw System* | 69.3 | 82.2 | 87.6 | 82.7 | 70.1 |
| Mid and East Antrim | 2745.2 | 3213.2 | 3380.5 | 3178.5 | 2705.8 |
| *PV GIS % Output of 4Kw System* | 68.6 | 80.3 | 84.5 | 79.5 | 67.6 |
| Mid Ulster | 2737.4 | 3236.8 | 3445.9 | 3259.1 | 2771.9 |
| *PV GIS % Output of 4Kw System* | 68.4 | 80.9 | 86.1 | 81.5 | 69.3 |
| Newry Mourne and Down | 2750.9 | 3213.2 | 3393.4 | 3208.1 | 2746.3 |
| *PV GIS % Output of 4Kw System* | 68.8 | 80.3 | 84.8 | 80.2 | 68.7 |

Each centroid location had five orientations assessed at 45-degree intervals on the compass as displayed in Table 14. In broad terms, mostly related to climatic variables, the further east the location in the province the more sunshine hours available. Ards and North Down Council area has the highest solar output for a given PV installation while Derry and Strabane Council area has the lowest. The PV output PV system percentages were integrated into the dwelling polygon data using the following graduated intervals by multiplying the roof area potential generation kilowatts figure for each building by the modelled output reduction factor for each LGD centroid from the PV GIS webtool tool. This produced a result indicating annual PV capacity in Kilowatts at the eleven centroid locations which were then adjusted for a range of roof top availability percentages of 22% to 47%.

**Table 14 PV GIS Percentage System of Rated Outputs at 45 Degree Interval Orientations**

| LGD | W 90 + | West 45 to 89 | SW 44 | South 0 | SE -44 | East- 45 to -89 | E -90 + |
|---|---|---|---|---|---|---|---|
| Antrim and Newtownabbey | 68.7 | 80.8 | 85.6 | 85.6 | 85.6 | 80.8 | 68.7 |
| Ards and North Down | 72.5 | 86.9 | 92.6 | 92.6 | 92.6 | 86.8 | 72.4 |
| Armagh City Banbridge and Craigavon | 69.9 | 83.0 | 88.5 | 88.5 | 88.5 | 83.6 | 70.7 |
| Belfast | 70.3 | 83.6 | 89.1 | 89.1 | 89.1 | 83.9 | 70.8 |
| Causeway Coast and Glens | 66.2 | 77.8 | 82.4 | 82.4 | 82.4 | 77.8 | 66.3 |
| Derry City and Strabane | 64.3 | 75.0 | 79.2 | 79.2 | 79.2 | 75.1 | 64.7 |
| Fermanagh and Omagh | 66.5 | 77.9 | 82.5 | 82.5 | 82.5 | 78.1 | 67.0 |
| Lisburn and Castlereagh | 69.3 | 82.2 | 87.6 | 87.6 | 87.6 | 82.7 | 70.1 |
| Mid and East Antrim | 68.6 | 80.3 | 84.5 | 84.5 | 84.5 | 79.5 | 67.6 |
| Mid Ulster | 68.4 | 80.9 | 86.1 | 86.1 | 86.1 | 81.5 | 69.3 |
| Newry Mourne and Down | 68.8 | 80.3 | 84.8 | 84.8 | 84.8 | 80.2 | 68.7 |

## 4.0 Potential PV Rooftop Generation Results

The potential for Domestic rooftop PV generation in the province was calculated using the following factors and assumptions.

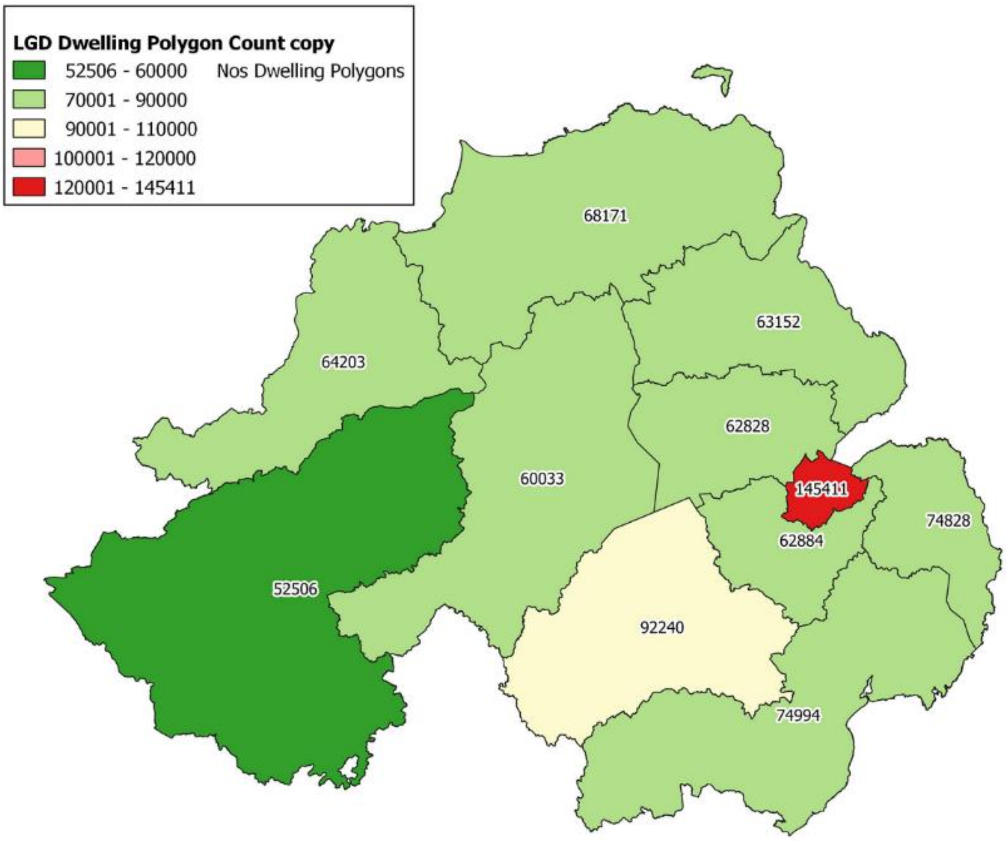
a) The total footprint area in $m^2$ of Dwellings and Garages by LGD in the province
b) Assumed that 100% of roofs are pitched
c) An assumed roof pitch of 35 degrees giving a multiplication adjustment factor of 1.2.
d) PV roof availability in a range of 22% to 47%
e) A PV panel size of $1.6m^2$
f) A PV panel generating capacity of 250 Wp
g) PV annual system generation output percentage based on solar irradiance levels at LGD centroids and orientation of individual polygons in a range of + or - 90 degrees of due south.

The GIS analysis of the OSNI BaseMap 2020 data determined that there were 821,250 dwelling polygons in the province and 426,857 domestic buildings/garages polygons in the size range 12m$^2$ to 75m$^2$. The total number of building polygons analysed was 1,248,107 and the area of the dwellings was 67,289,866 m$^2$ and the total area of the garages was 13,115,428m$^2$. The mean dwelling rooftop size was 81.9 m$^2$ and the median size was 63.2m$^2$, while mean garage rooftop size was 30.7 m$^2$ and the median size was 25.7m$^2$. The spatial analysis of dwellings by Local Government District produced the following distribution with Belfast City Council having both the largest number of dwellings 146,176 and marginally the largest dwelling footprint area of 8,207,131m$^2$.

**Table 15 Area by dwelling polygons across LGDs**

| LGD NAME | Nos Dwelling Polygons | Area Dwelling Polygons m$^2$ |
|---|---|---|
| Antrim and Newtownabbey | 62,828 | 4,857922 |
| Ards and North Down | 74,828 | 6,128598 |
| Armagh City Banbridge and Craigavon | 92,240 | 8,035270 |
| Belfast | 145,411 | 8,207131 |
| Causeway Coast and Glens | 68,171 | 6,271116 |
| Derry City and Strabane | 64,203 | 4,815268 |
| Fermanagh and Omagh | 52,506 | 5,310441 |
| Lisburn and Castlereagh | 62,884 | 5,144128 |
| Mid and East Antrim | 63,152 | 5,107696 |
| Mid Ulster | 60,033 | 6,038553 |
| Newry Mourne and Down | 74,994 | 7,373743 |
| Total | 821,250 | 67,289,866 |

**Figure 25 Dwelling Polygons by LGD**



This "raw" polygon data was used to calculate the generation potential (Table 16) using the factors listed in points c) to g) above.

**Table 16 Results Dwellings PV Annual Generation Potential MWh**

| Local Government District | 100% Dwelling Roof Availability MWh | 22% Availability MWh | 35% Availability MWh | 47% Availability MWh |
|---|---|---|---|---|
| Antrim and Newtownabbey | 756260 | 166377 | 264691 | 355442 |
| Ards and North Down | 1028678 | 226309 | 360037 | 483479 |
| Armagh City Banbridge and Craigavon | 1289920 | 283782.4 | 451472 | 606262 |
| Belfast | 1325481 | 291605.8 | 463918.4 | 622976 |
| Causeway Coast and Glens | 939930 | 206784.6 | 328975.5 | 441767 |
| Derry City and Strabane | 695455 | 153000.1 | 243409.3 | 326864 |
| Fermanagh and Omagh | 798311 | 175628.4 | 279408.9 | 375206 |
| Lisburn and Castlereagh | 833995 | 183478.9 | 291898.3 | 391978 |
| Mid and East Antrim | 786177 | 172958.9 | 275162 | 369503 |
| Mid Ulster | 943131 | 207488.8 | 330095.9 | 443272 |
| Newry Mourne and Down | 1138320 | 250430.4 | 398412 | 535010 |
| Total | 10535658 | 2317845 | 3687480 | 4951759 |

**Figure 26 Potential Dwelling Rooftop Generation GWh at 35% Roof Availability**

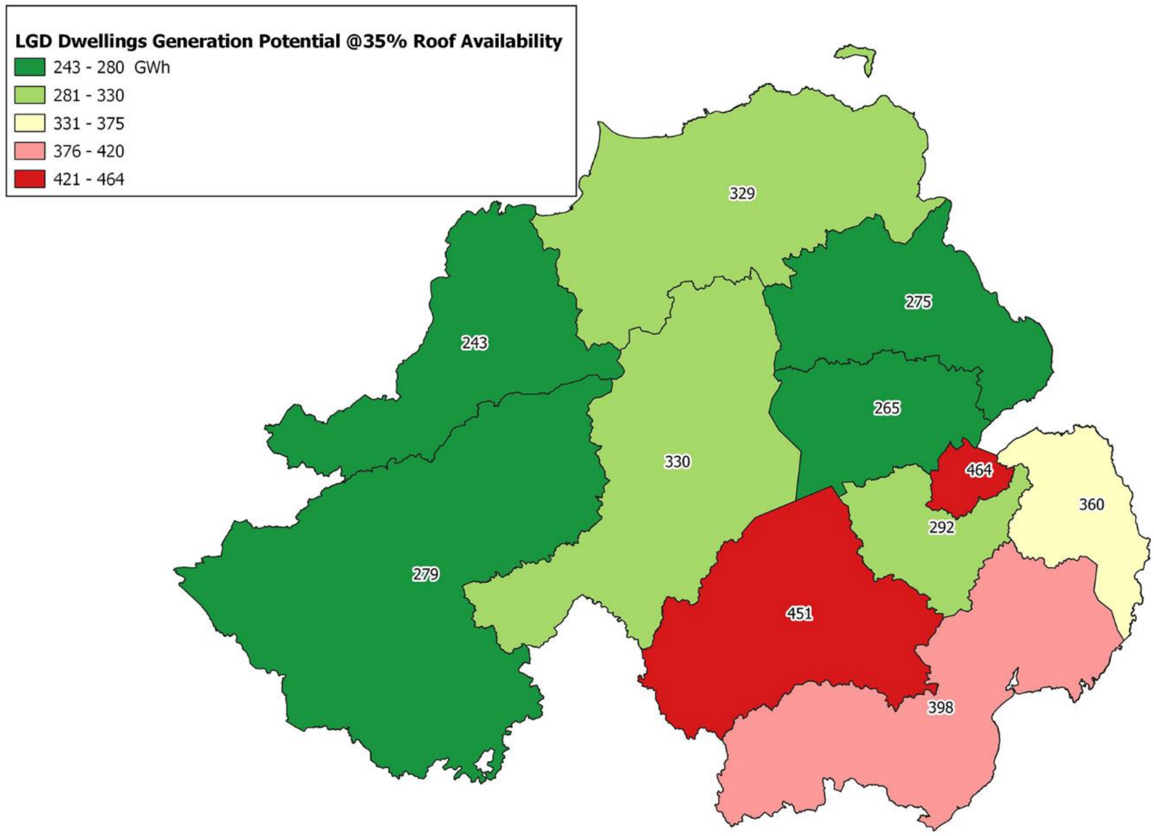


**Table 17 Results Domestic Garages**

| LGD NAME | Nos Garage Polygons 12 to 75m$^2$ | Area of Garages m$^2$ |
|---|---|---|
| Antrim and Newtownabbey | 26468 | 747444 |
| Ards and North Down | 31052 | 788493 |
| Armagh City Banbridge and Craigavon | 54903 | 1725884 |
| Belfast | 36862 | 647173 |
| Causeway Coast and Glens | 40902 | 1331259 |
| Derry City and Strabane | 26790 | 770628 |
| Fermanagh and Omagh | 50288 | 1848869 |
| Lisburn and Castlereagh | 29865 | 835728 |
| Mid and East Antrim | 33223 | 1041697 |
| Mid Ulster | 45699 | 1667751 |
| Newry Mourne and Down | 50805 | 1710502 |
| **Total** | **426857** | **13,115,428** |

This "raw" polygon data was used to calculate the generation potential (see Table 18) using the factors listed in points c) to g) above.

**Table 18 Garage Roof top Total Potential at Percentage Availability Ranges**

| Local Government District | 100% Garage Roof Availability GWh | 22% Availability GWh | 35% Availability GWh | 47% Availability GWh |
|---|---|---|---|---|
| Antrim and Newtownabbey | 116 | 26 | 41 | 55 |
| Ards and North Down | 132 | 29 | 46 | 62 |
| Armagh City Banbridge and Craigavon | 277 | 61 | 97 | 130 |
| Belfast | 105 | 23 | 37 | 49 |
| Causeway Coast and Glens | 200 | 44 | 70 | 94 |
| Derry City and Strabane | 111 | 2 | 4 | 5 |
| Fermanagh and Omagh | 278 | 61 | 97 | 131 |
| Lisburn and Castlereagh | 133 | 29 | 47 | 62 |
| Mid and East Antrim | 160 | 35 | 56 | 75 |
| Mid Ulster | 261 | 57 | 91 | 123 |
| Newry Mourne and Down | 264 | 58 | 93 | 124 |
| Total | 2037 | 426 | 678 | 911 |

**Figure 27 Potential Garage Rooftop Generation GWh at 35% Roof Availability**

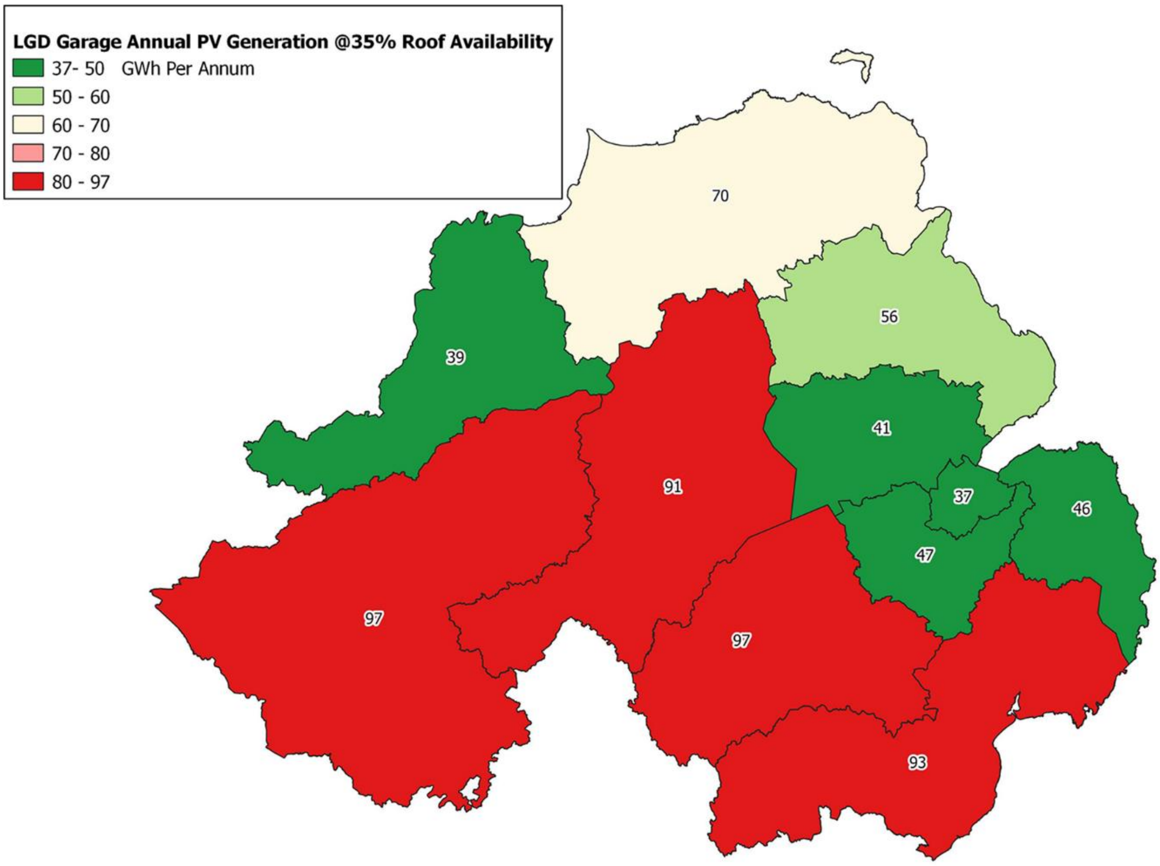



**Table 19 Results Dwelling Garage Roof Top PV Generation Potential MWh 100% Roof Availability**

| Local Government District | Dwellings Roof Capacity MWh | Garage Roof Capacity MWh | Dwellings and Garage Roof MWh | Dwellings and Garage Roof MWh |
|---|---|---|---|---|
| Antrim and Newtownabbey | 756 260 | 116419 | 872679 | 873 |
| Ards and North Down | 1028678 | 132483 | 1161161 | 1161 |
| Armagh City Banbridge and Craigavon | 1289920 | 277090 | 1567010 | 1567 |
| Belfast | 1325481 | 104617 | 1430098 | 1430 |
| Causeway Coast and Glens | 939930 | 199645 | 1139575 | 1140 |
| Derry City and Strabane | 695455 | 111272 | 806727 | 807 |
| Fermanagh and Omagh | 798311 | 277678 | 1075989 | 1076 |
| Lisburn and Castlereagh | 833995 | 132962 | 966957 | 967 |
| Mid and East Antrim | 786177 | 160463 | 946640 | 947 |
| Mid Ulster | 943131 | 260952 | 1204083 | 1204 |
| Newry Mourne and Down | 1138320 | 264321 | 1402641 | 1403 |
| Total | 10,535,658 | 2,037,902 | 12,573,560 | 12574 |

The results for the 35% rooftop availability for dwellings and domestic garages indicate that a potential annual generation of 4401GWh could be achieved. Figure 28 indicates the distribution of generation by LGD in the province. As can been seen Belfast City Council and Armagh, Banbridge and Craigavon Council have the highest potential PV rooftop generating capacity in the province.

**Table 20 Dwelling and Garage Generation Potential Rooftop Availability Percentages**

| Local Government District | 100% Dwelling and Garage Roof Availability GWh | 22% Roof Availability GWh | 35% Roof Availability GWh | 47% Roof Availability GWh |
|---|---|---|---|---|
| Antrim and Newtownabbey | 873 | 192 | 305 | 410 |
| Ards and North Down | 1161 | 255 | 406 | 546 |
| Armagh City Banbridge and Craigavon | 1567 | 345 | 548 | 736 |
| Belfast | 1430 | 315 | 501 | 672 |
| Causeway Coast and Glens | 1140 | 251 | 399 | 536 |
| Derry City and Strabane | 807 | 177 | 282 | 379 |
| Fermanagh and Omagh | 1076 | 237 | 377 | 506 |
| Lisburn and Castlereagh | 967 | 213 | 338 | 454 |
| Mid and East Antrim | 947 | 208 | 331 | 445 |
| Mid Ulster | 1204 | 265 | 421 | 566 |
| Newry Mourne and Down | 1403 | 309 | 491 | 659 |
| Total | 12574 | 2766 | 4401 | 5910 |

**Figure 28 Total Annual Residential Generation GWh Potential @35% Roof Availability by LGD**

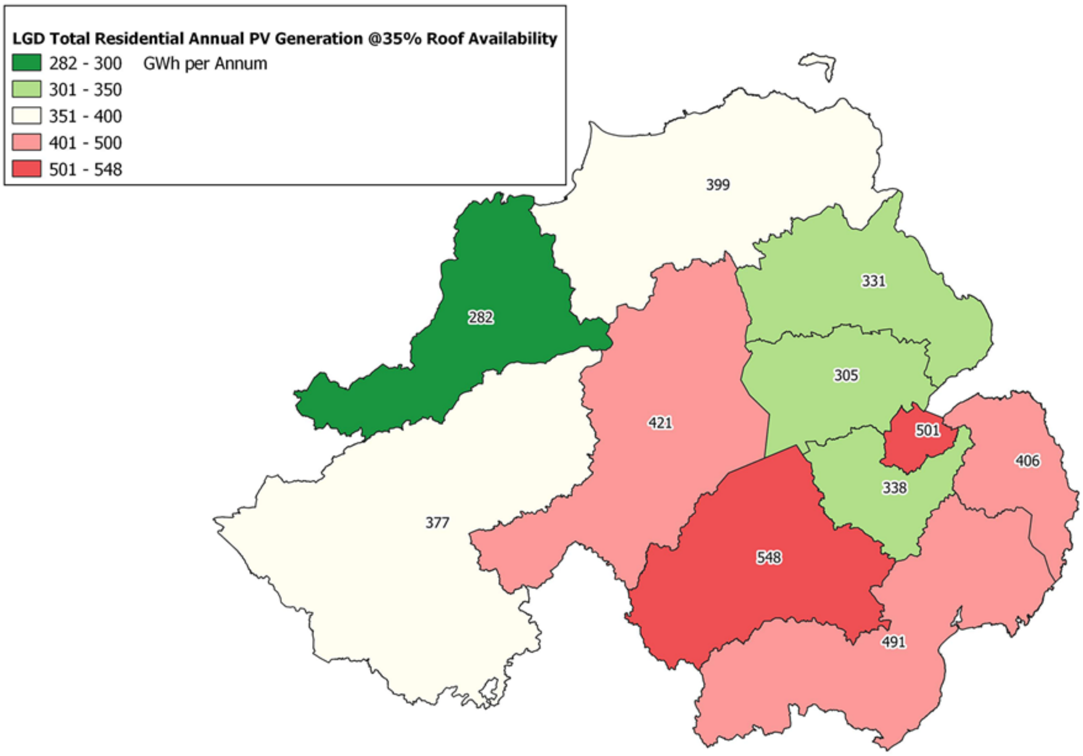
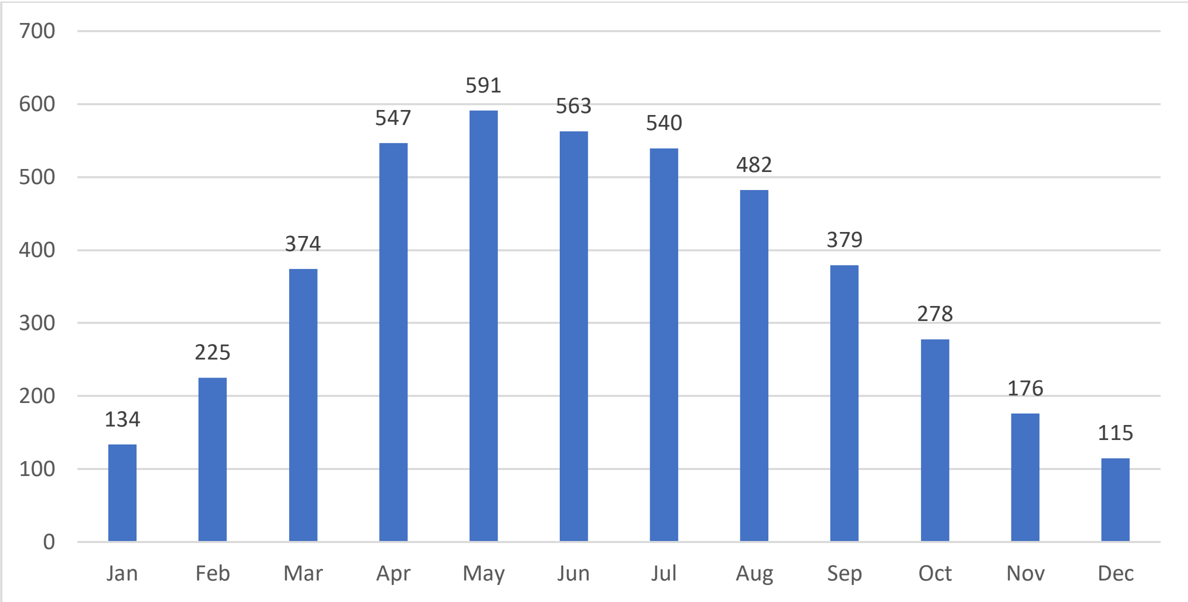


Figure 29 below provides a monthly breakdown of the potential electricity generation for residential rooftop PV at 35% rooftop availability.

**Figure 29 Monthly Breakdown of Generation Potential using 35% Rooftop availability 4401 GWh based on the NI Centroid Location for Solar Irradiation.**



## 5.0 Case Study PV Installation Generation and Usage

Exploratory research on a small number of case study households has been undertaken to determine PV System Generation Outputs in kWh, the Seasonal and Monthly variation of outputs and the extent to which household electricity generated from PV is exported to the electricity grid with aim of assessing residential PV potential generation in N. Ireland.

Six case study households have been participating in the research for two years and it is intended to expand the number of households to twenty in the near future. The six households have provided details of their PV system size in Kilowatts, whether they had PV water heating (Solar Plus enhancement) and the orientation of the PV system. The Case Study households' details are listed below. (Table 21)

**Table 21 Case study households**

| Study Nos | Case Study Household | PV System Size kWp | Nos Panels | Orientation | PV Water Heating |
|---|---|---|---|---|---|
| 1 | IS | 2.0 | 8 | South East | No |
| 2 | CM | 3.25 | 13 | | No |
| 3 | CL | 4.0 | 16 | South East/South West | Yes |
| 4 | JB | 4.0 | 16 | South East/ South West | Yes |
| 5 | DW | 4.0 | 16 | South | No |
| 6 | SM | 5.28 | 22 | South East | Yes |

## 5.1 Household PV Impacts on Energy Imported from the Electricity Network.

The study entailed a comparison pre and post PV installation household electricity usage and the amount of electricity diverted to solar water heating by the collection of monthly readings from the solar water heaters.

In relation to the impact of PV installations on the kWh of electricity imported from the electricity network the results in Table 22 indicate that PV generation reduced electricity consumption from the grid by approximately 32% in three households compared to pre installation levels. The results from the four household where this data was available indicates an average reduction of electricity consumption of 26%. While this represents a very small sample, the results are in line with findings of McKenna et al. (2018:448) which concluded that PV installations produced a "reduction of the average UK household's annual electricity demand of 24%" and Schopfer et al. (2018:241) a 29% reduction. It is interesting to note that none of the households had undertaken a pre and post installation of electricity consumption assessment prior to engaging with the study.

**Table 22 impact of PV installations on the kWh of electricity imported from the electricity network**

| | SM Electricity Usage KwH | SM % Post PV Reduction | CI Electricity Usage KwH | CL % Post PV Reduction | DW Electricity Usage KwH | DW % Post PV Reduction | IS Electricity Usage KwH | IS % Post PV Reduction | BM Electricity Usage KwH |
|---|---|---|---|---|---|---|---|---|---|
| Pre Solar PV | 5900 | | 5294 | | 3300 | | 3025 | | |
| Post PV 2015 | 3689 | 37.5 | 3959 | 25.2 | 2345 | 28.9 | | | |
| Post PV 2016 | 3608 | 38.8 | 4356 | 17.7 | 2216 | 32.8 | | | |
| Post PV 2017 | 4127 | 30.1 | | | 2360 | 28.5 | | | |
| Post PV 2018 | 4459 | 24.4 | | | 2359 | 28.5 | | | |
| Post PV 2019 | | | | | 1981 | 40.0 | | | |
| Post PV 2020 | 4683 | 20.6 | 6448 | -21.8 | 2245 | 32.0 | 2007 | 33.7 | |
| Average % | | 30.3 | | 7.0 | | 31.8 | | 33.7 | |

There is evidence of energy use rebound in two of the household with electricity consumption increasing after an initial drop.

5.2 **Solar Plus Technologies: PV Solar Water Heaters**

O'Shaughnessy et al. (2018:11) discuss the concept of residential "Solar Plus" which they describe as "the combination of PV, energy storage, and load control providing an integrated approach to PV deployment". One aspect of this approach is the use of solar PV "to divert the surplus solar photovoltaic energy generated in the home to heat the water in the household hot water storage tank" (Marlec UK accessed 01/04/2021). This is achieved by the installation of devices such as either a Solar iBoost or Immersun.

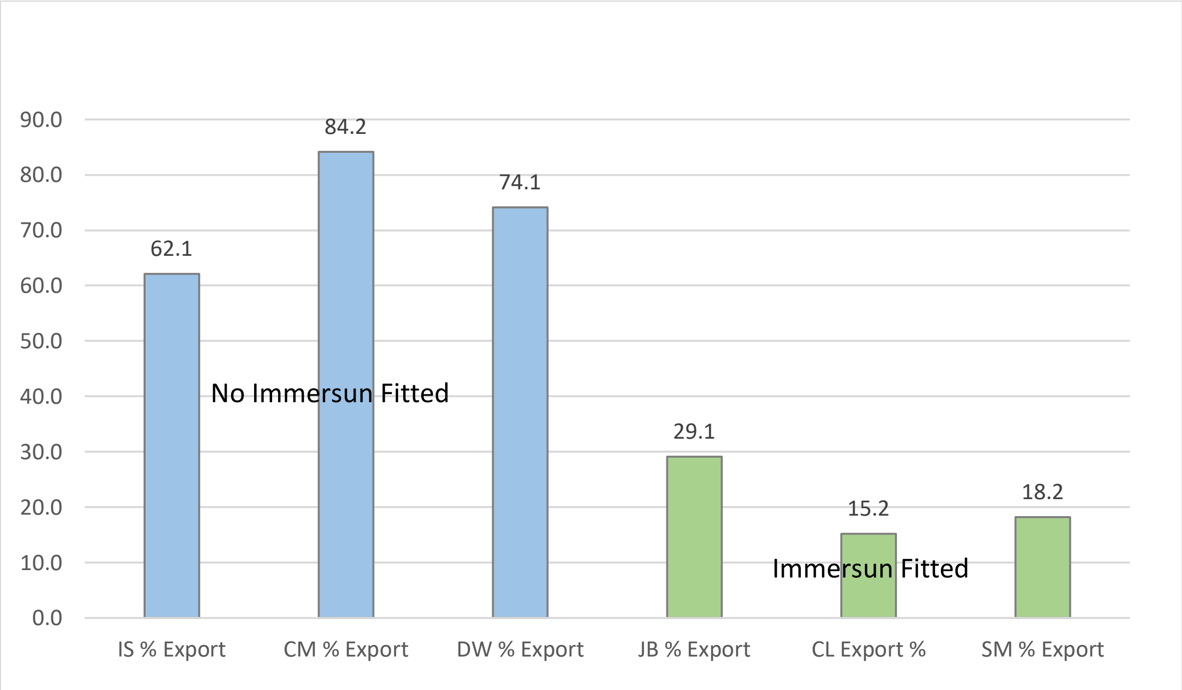
These devices monitor household PV electricity generation and once generation exceeds usage in the dwelling, they automatically switch on the immersion hot water heater, in order that the excess electricity is used within the home, rather than being exported to the grid. PV water heaters cost approximately £300.

**5.3 Assessing the Impact of PV Water Heaters on Household Electricity Usage**

This research has gathered details of PV electricity generation and electricity exported to the network from 6 case study households. As can be seen in Figure 29 below those households with solar water heating installed had an average electricity export figure of 20.8% in 2020 while those with no PV water heating installed had an average export percentage of 73.1%. As an example, one case study household in 2020 diverted 1438 kWh of PV electricity generation to water heating.

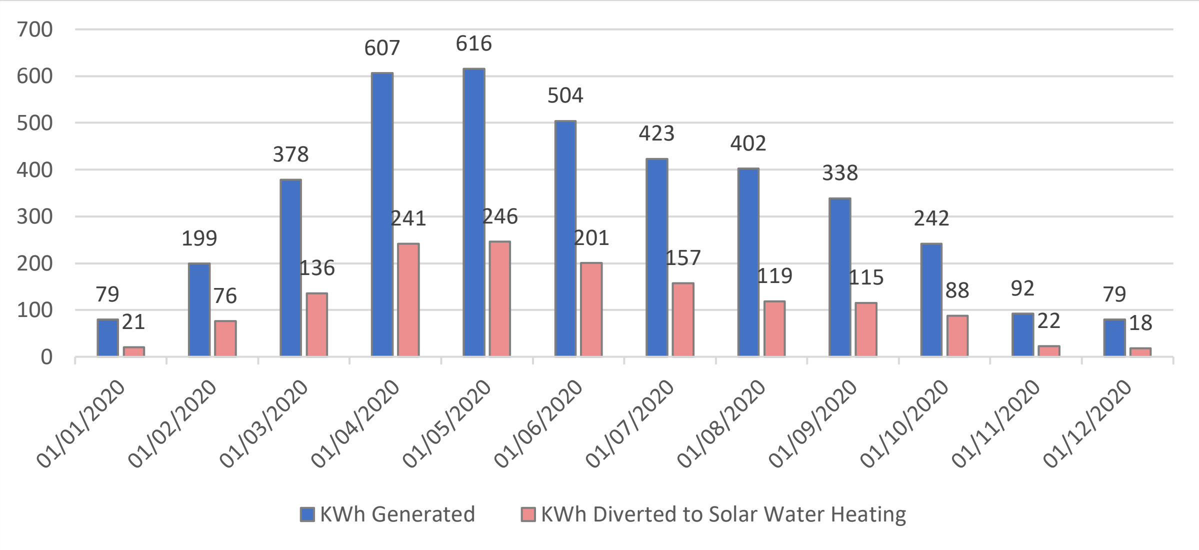
One litre of kerosene (central heating oil) is equivalent to 10.4 kWh hours of electricity so in this instance 138 litres of oil were saved (£54, Sept 2021 Prices) and the household benefitted from hot water. The technology does rely on dwellings having a hot water tank being fitted so that the water can be stored.

**Figure 30 Case Study Households % PV Generation Exported to Grid 2020**




In addition PV solar water heaters can provide a worthwhile proportion of household hot water need in the months between March and September, 3.5kWh will heat 100 litres of water by $30^0$ C. The graph below illustrates hot water generation in a case study household (Figure 31 overleaf).

**Figure 31 Case Study Household PV and Hot Water Generation**




Information was also obtained from PowerNI detailing high level electricity generation figures from PV systems registered with the organisation. Power NI has 9,700 PV stations registered with it, 8,600 of which have an installed capacity of 6.5Kw or less, likely to be residential. The total Installed Capacity of the 9,700 PV systems is 64MW and the 8,600 <6.5 Kw systems have an installed capacity of 38MW. Table 23 below indicates the total and exported to the PV generation.

**Table 23 total and exported to the PV generation**

| Year | Installed Capacity MWh | Generation Total MWh | Exported to Network MWh |
|---|---|---|---|
| 2020 | 64 | 43.6 | 13.4 |
| 2019 | 64 | 44.1 | 13.4 |

The <6.5Kw systems at 38MW equals 59% of generating capacity. Using this percentage 59% of total generation (44MW) is 26 MW and 13.4MW or 52% of this total is exported to the electricity network. The PowerNI data does not distinguish between those PV systems that have Solar + technologies fitted and those that do not, but the data does provide an PV generation export figure of 52% of from a large sample which is a useful comparator. It therefore provides an indication of the impact that PV solar Water heaters have on PV household electricity exports i.e. households using the technology export around 20% of generation and those that do not export well in excess of 50% of generation.

## 6.0 Findings and Conclusions

### 6.1 Solar PV Installation Numbers

The number of PV installations in the province is just over 22,000 (19,680 less than 6.5 Kw indicating likely residential), this figure equates to approximately 2.5% of the housing stock having Solar PV installed. The number of PV installations appears to have remained relatively constant since 2018. PV installations in the province rose steadily between 2013 and 2016, encouraged by the incentive provided by the Renewables Obligation scheme for small scale renewable generation. There were peaks in the number of PV installations in 2014, 2015 and 2016, coinciding with the staged reduction in the payments by the ROC scheme, with applicants attempting to avail of the scheme before the rate cuts were implemented. The ending of the ROCs schemes has reduced new PV installations to very low numbers annually. It is apparent that the uptake of residential PV is highly reliant on some form of financial incentive scheme.

**Table 25 ROCs schemes per annum**

| Technology | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| Solar PV (up to 50Kw) | 4 ROCs | 3 ROCs | 2 ROCs | ROCs end |

### 6.2 PV Installations Locations

The results from the analysis of both the OFGEM and NIEN PV data sets indicates that approximately 66% of PV installations in the province are located outside settlement development limits in rural areas. There is also a marked difference in installation rates between Local Authorities in the Greater Belfast Area than the remainder of the province. This poses the questions as to why rural communities adopted PV technology in greater numbers than urban? What factors prompted the differential adoption of PV and why was the adoption much less prevalent in urban areas and the Greater Belfast Area with the same incentive scheme operating across Northern Ireland?

### 6.3 PV Impacts on household Electricity Consumption

Research from a small number of local case study households and supported by other cited literature indicates that households with PV installed typically have a reduction of 30% in electricity imported from the grid compared to pre-install electricity import consumption.

### 6.4 Water Heating from PV

Households which have “Solar Plus” devices such as PV water heaters (costing £300) benefit from a worthwhile proportion of their hot water needs being met by their PV systems between the months of March and September. In addition, these households export approximately 20% of generation to the grid while those with no water heaters export approximately 70%.

### 6.5 Characteristics of Current Solar PV Households

This research set out to characterise households that have installed solar PV systems in their homes in Northern Ireland. The results indicate that PV adopters to date are households that are owner occupiers from rural, less densely populated areas and that higher levels of income, employment and education have a positive effect on PV adoption. It is therefore axiomatic that the converse is also case in that those households in rented (especially private rented) accommodation, exhibiting lower levels of income, employment and education, located in urban areas are least likely to have installed solar PV systems.

## 6.6 The Potential for Residential PV Generation in N. Ireland

There are 821,250 dwelling and 4,26858 domestic garage building polygons in the province in the OSNI database with a rooftop area of 67,289,866m$^2$ (dwellings) and 13,115,428m$^2$ (garages) totalling 80,405,294m$^2$ (80.4 Km$^2$) of residential roof area.

The following assumptions were used in the calculation of the residential PV rooftop potential.

i all roofs are pitched with an angle of 35 degrees,
ii only domestic garages with areas of between 12m$^2$ and 75m$^2$ were included
iii PV panels have an area of 1.6m$^2$ and
iv PV panels have an output of 250 watts.

Using a rooftop availability figure of 35% for PV the assessed residential (dwellings and garages) potential annual generation for the province is 4401 GWh. In 2016-17 residential electricity consumption in Northern Ireland was 2907 GWh with a monthly average consumption of 242 GWh. Rooftop Domestic Solar PV has the potential to generate significantly in excess of this demand on an annual basis and exceeds monthly demand in the months March to October.

## 6.7 Conclusion

Even in the comparatively overcast skies of Northern Ireland residential Solar PV installations with solar water heating, can provide 30% of household annual electricity consumption and make a worthwhile contribution to household hot water requirements between the months of March and September. The previous ROCs incentive scheme encouraged the uptake of the technology but the schemes closure in 2017 halted new installations and currently approximately only 2.5% of households make use of PV technology in the province. Furthermore, the ROCs scheme was clearly an attractive proposition to particular sections of the community, but this research has established that as a policy driver its success was far from spatially uniform, with urban areas in particular not availing of the initiative.

Solar PV is a mature technology and it has the potential to make a very significant contribution to household energy needs, reducing fuel poverty and meeting the goal of net carbon zero. However, as this research has established in the absence of financial incentives to households Solar PV is unlikely to be widely adopted within the residential sector.

*Policy note:*

*The OFGEM data utilised in this research was provided at SOA level. Results of a detailed statistical analysis indicate that probably factors such as neighbourhood peer clusters have encouraged PV adoption and that it is more commonly installed in detached houses.*

*However, it is not possible to attach a degree of certainty to these findings using SOA level data, further analysis using full address data, if it became available, would provide additional confidence on factors such as clustering and house type.*

## References


1. Committee on Climate Change, Net Zero the UK's contribution to stopping Global Warming, May 2019, P.23 https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

2. Department for the Economy, Energy in Northern Ireland 2020, P39

3. European Commission, PV GIS Performance of Grid Connected ( https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP

4. How to measure the pitch of your roof | DWB Group accessed 05/05/21

5. Marlec UK Solar iBoost + Brochure https://www.marlec.co.uk/wp-content/uploads/2016/02/Solar-iBoost-Brochure-v3-A4-3pg.pdf

6. McKenna E, Pless J, and Darby S, Solar photovoltaic self-consumption in the UK residential sector: new estimates from a smart grid demonstration project, Energy Policy Volume 118 July 2018, P488.

7. O'Shaughnessy E, Cutlera D, Ardania K, Margolisa R, Solar plus: Optimization of distributed solar PV through battery storage and dispatchable load in residential buildings, Applied Energy, 2018, P11

8. Schopfera S, Tiefenbecka V, Staakeb T, Economic assessment of photovoltaic battery systems based on household load profiles, Applied Energy Volume 223, August 2018, P241

9. Tyagi V. et al. / Renewable and Sustainable Energy Reviews 20 (2013) 443–461461

10. Wiginton H, Nguyen H, Pearce J, Quantifying rooftop solar photovoltaic potential for Regional Renewable Energy Policy, Computers, Environment and Urban Systems, Department of Mechanical and Materials Engineering, Queen’s University, Canada K7L 3N6, 2010, P352