Georgeham Parish Council Rooftop Solar PV Analysis

30/06/2022

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1 Introduction

Georgeham Parish Council commissioned CSE to conduct a detailed solar photovoltaics (PV) mapping exercise as part of a wider climate action plan for the area. CSE's solar PV model estimates the potential electricity generation from the installation of PV panels on the buildings within any given region of the UK, in this case being applied to the parish level. There is an associated cost-benefit model which calculates the financial profitability in terms of Internal Rate of Return (IRR) of all the potential PV installations. Together, the two models aim to evaluate each section of roofing of each building in the region for both the technical and financial viability of a solar PV installation.

2 Methodology

2.1 Solar photovoltaics

Solar PV systems use solar cells to generate electricity directly from sunlight. The solar cells are packaged together into panels or modules and are normally roof-mounted as a 'solar array'. Most systems are grid-connected, so electricity generated by the solar cells can either be exported to the national electricity grid or can be used directly in the building where it was generated via a solar inverter. Domestic-scale battery systems are available that provide storage for any excess power generated, which can then be used within the building when needed. The capital cost of a battery system is currently still relatively unaffordable for most people, but prices have been consistently falling.

Other forms of solar PV technology are becoming more common in the UK, such as solar tiles, which can be integrated into new buildings or refurbishments alongside conventional roofing tiles or slates.
For best performance in the UK, solar PV systems need to be inclined at an angle of 30-40 degrees from horizontal, face due south and be clear of the shade of trees and buildings. Potential shading effects should be considered all year round as the position of the sun varies seasonally.

2.2 CSE's Solar PV Model

2.2.1 Method

The model uses LiDAR data for a specified geographical area; in this case Georgeham Parish. LiDAR data tells us the height above sea-level of each metre-by-metre square section of the area (that is if data at a resolution of $1m^2$ is available for that area, which most areas of the UK now have). It also uses Ordnance Survey building footprint polygons for the area to be modelled. The process/method used is as follows:

1. Model horizons: using the LiDAR data, the model builds a horizon profile for each point of LiDAR data that falls within the footprint of a building. This is the horizon height in degrees from horizontal in a ring around the building, as if an observer was standing on the roof of the building and reporting how much sky could be seen in each direction.
2. Detect roof planes: for each building, the model detects the various roof planes that make up the roof of the building. For example, it would detect one roof plane in a flat-roofed building, two in a building with gables, and four in a building with a hip roof. The higher-resolution the LiDAR data is, the more accurate this process is. This tells us the size and compass orientation of each potential PV panel site.

3. Exclude unsuitable roof sections: Roof sections are excluded from the model for a range of reasons:
    - They are too north-facing;
    - They are angled too steeply;
    - They are too overshadowed to the south, southeast or southwest (using the horizon data calculated earlier);
    - The roof section is too small for a useful installation.
4. Calculate electricity output: using a tool called PV-GIS, the electricity generated by an installation with a given location, size, compass orientation and horizon model is calculated. This includes modelling losses due to temperature, reflection and cabling/inverters.
5. Perform cost-benefit analysis: installation costs are informed by the latest UK market data and reflect the significant (and continuing) cost reductions in PV system components in the last 2-3 years. The IRR is calculated in descending order of profitability for each potential PV installation of each building. For example, if a building has three potential PV sites on its roof called P1, P2 and P3, the IRR is calculated for the following combinations of installations: [P1], [P1 P2], and [P1 P2 P3]. This is so the least financially profitable site (P3) is only considered if it would be worth installing both P1 and P2.

The resulting outputs consist of GeoPackages – databases of geospatial data - showing the roof planes which are suitable for solar PV installations, with the ability to categorise them e.g. by tenure, residence type, or IRR. This data can also be presented in a spreadsheet with one row per roof plane. Each roof plane (row) has given a peak power (MW), usable area (m^2), total yield (kWh/year), yield per roof area (kWh/m^2/year), installation cost (£) and IRR band (% profit over 25 years). Figure 1 provides a visual representation of the model outputs.

The model outputs also indicate buildings which might already have rooftop PV and buildings which have listed building status, where installing solar PV might not be possible.

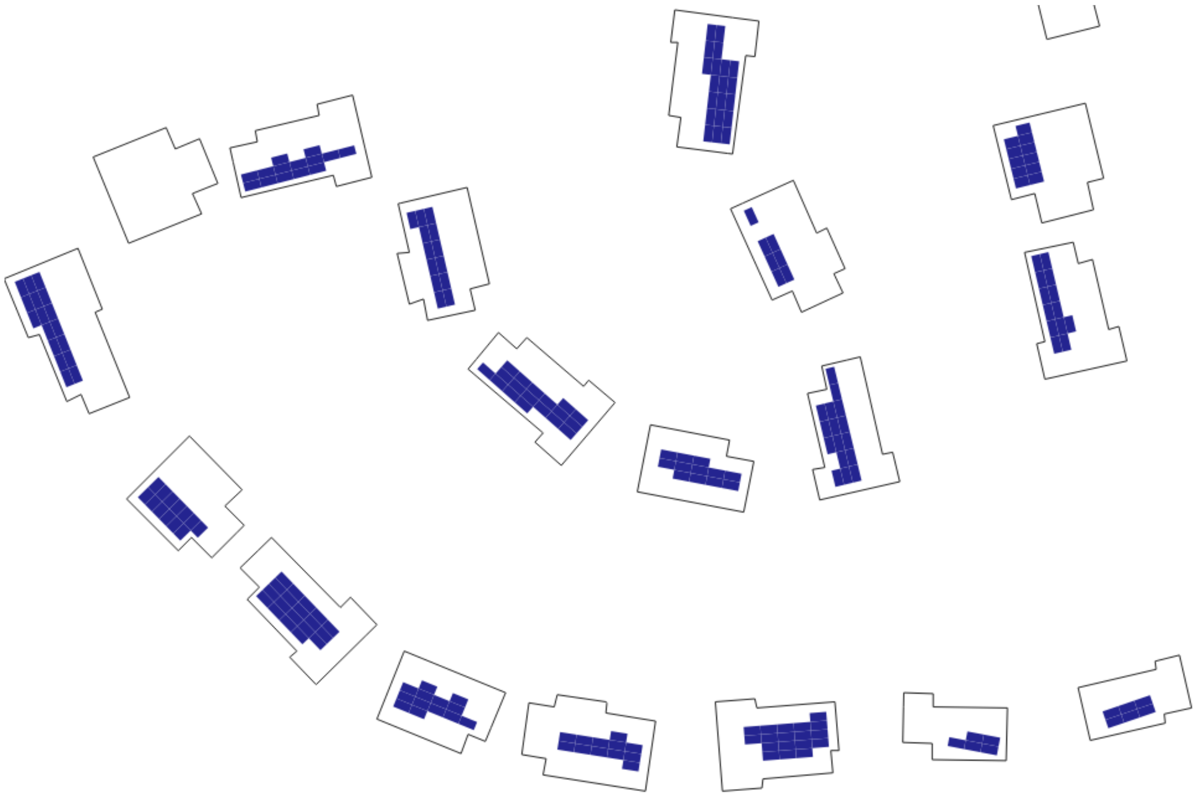

Figure 1: A snapshot of buildings with modelled PV panels within Georgeham Parish

2.2.2 Constraints

- If there is no LiDAR coverage for the area, solar PV modelling will not be possible. The quality of the outputs will be reduced if there is only low-resolution (greater than 1m by 1m resolution) LiDAR coverage.
- If there are new buildings that outdate the LiDAR data, modelling will not be possible for those buildings.
- The PV model does not detect buildings unsuitable for PV installation due to roof weakness.
- The PV model does not assess electricity grid capacity constraints.

The LiDAR coverage in Georgeham Parish Council is shown in Figure 2. LiDAR covers 78% of the area and 91% of the buildings. The LiDAR coverage gap means that the villages of Darracott and North Buckland could not be included in this analysis. Further work could be done to conduct a LiDAR survey of this area to fill the gap. This can be carried out using UAV/drone equipment.

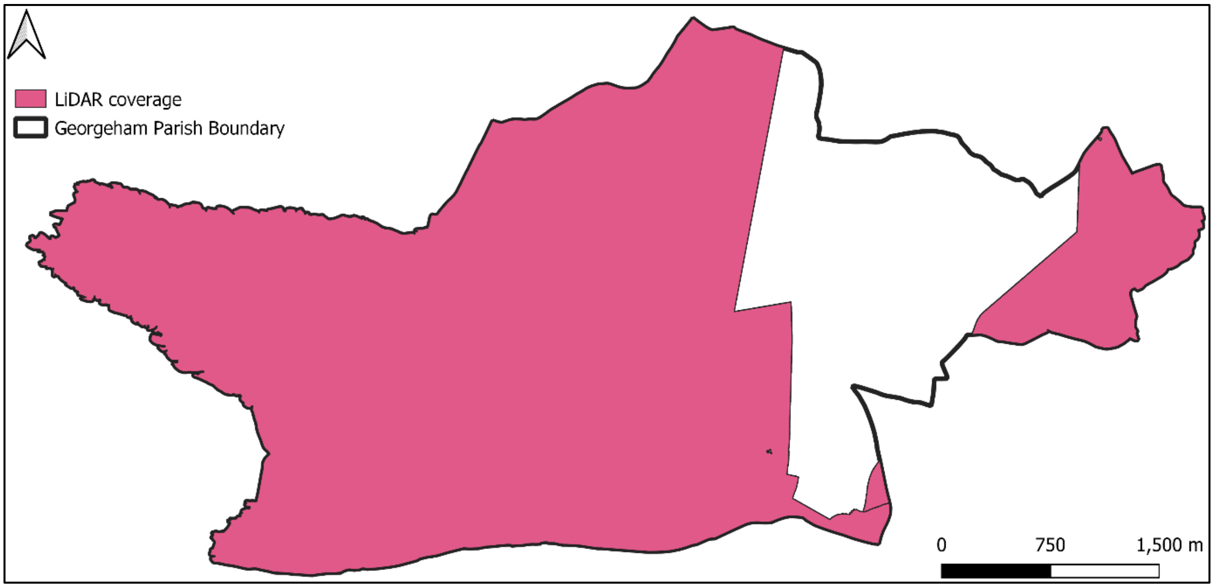

Figure 2*:* LiDAR coverage within Georgeham Parish

2.2.3 Assumptions used:

Within this analysis there are two different electricity cost parameters: 16.5p/kWh and 28p/kWh

- 16.5p/kWh: this assumes 50% of the electricity generated is used onsite; i.e. 50% of the electricity generated displaces the consumption of full rate grid electricity costs of 28p/kWh (reflecting the 1st April 2022 price cap) while the other 50% is sold to the grid through a smart export guarantee tariff of 5p/kWh[1]. This produces an average value of 16.5p/kWh for electricity generated by the solar PV systems.
- 28p/kWh with £4,000 fixed capital cost (battery): this assumes 100% of the electricity generated is used on site use. This is based on excess generation being stored in the battery, which is then discharged and used at times when no solar PV generation is available. In this scenario there is no need for the smart export guarantee as no electricity is exported to the national grid.

Each chosen value of electricity and the addition (or not) of a £4k fixed cost for a battery affects the outcome of the model in terms of the profitability of solar PV for each rooftop. This in turn affects the total number of financially viable installations and therefore the total potential MW capacity and GWh/year of electricity generation potential.

3 Results

3.1 Potential Capacity for Solar PV Generation

Using the 16.5p/kWh cost parameter, Georgeham Parish has the technical potential of 4.74 MW of rooftop solar PV capacity, which is estimated to generate 4.32 GWh/year of electricity (4,316,433 kWh/year).

In the 28p/kWh with a £4k battery fixed cost scenario, the parish has the technical potential capacity of 6.49 MW of rooftop solar PV, which is estimated to generate 5.68 GWh/year of electricity (5,678,007 kWh/year).

[1] https://www.ofgem.gov.uk/environmental-and-social-schemes/smart-export-guarantee-seg

3.2 Electricity Demand

The total consumption of electricity in Georgeham parish is available through LSOA-resolution data (North Devon 004C)[2]. For domestic users it was 5,612,901 kWh in 2020. There are 1,032 domestic electricity meters. The mean consumption per meter is 5,439 kWh and the median is 3,849 kWh.
Using the 16.5p/kWh parameter, 76.9% of the domestic electricity consumption in the parish could potentially be covered by rooftop solar generation. In theory, 50% of this would be used onsite and 50% exported as clean energy to the national electricity network, to offset any imported electricity.
In the 28p/kWh with battery scenario 101% of the domestic electricity consumption would be generated by rooftop solar PV over the course of a year.
Non-domestic (industrial and commercial) electricity consumption is not available at LSOA level. The parish falls into North Devon 004 MSOA which has a total non-domestic consumption of 5.31 GWh (shared over 559 electricity meters) with a mean consumption of 9,497 kWh per meter and a median of 4,392 kWh.

3.3 Distribution of Solar PV Potential

Figure 3 shows the distribution of rooftop solar PV across the parish at 16.5p/kWh for the value of the generated electricity, weighted by generation potential (kWh/year). It highlights areas that are dense with buildings as well as the bigger, more profitable roofs for solar PV.

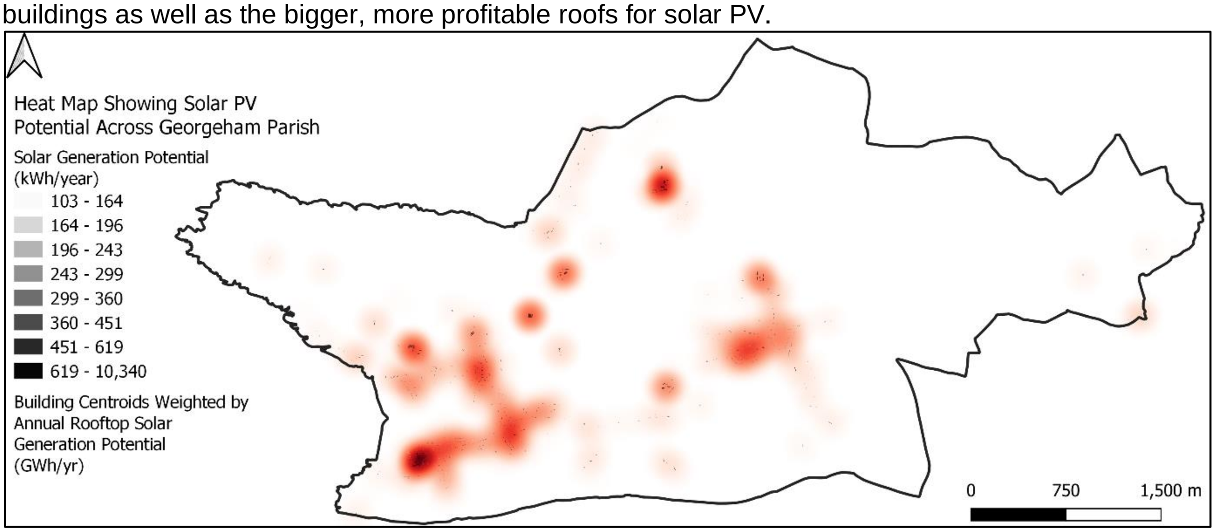

Figure 3: Solar PV distribution across Georgeham Parish (16.5p/kWh)

3.4 Installations

The model estimates that there is potential for 996 rooftop installations of solar PV within the area. This number is likely to vary in practise as mentioned in the limitations above. There are buildings not included in this analysis due to an absence of LiDAR coverage and out-of-date LiDAR data (where there are new buildings). This may mean that there is a higher potential for installations and electricity generation within the parish, however some roofs may not be suitable for solar PV due to structural reasons, which are not considered in this analysis.

[2] Lower and Middle Super Output Areas electricity consumption – BEIS
https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-electricity-consumption

3.5 Tenure

Figure 4 shows the breakdown of solar PV installations by OS categorisations of tenure. The highest proportion of installations are in owner occupied properties (601, 60%). There is a high percentage of unknown tenure which may be due to the prevalence of holiday lets within the parish (306, 31%).

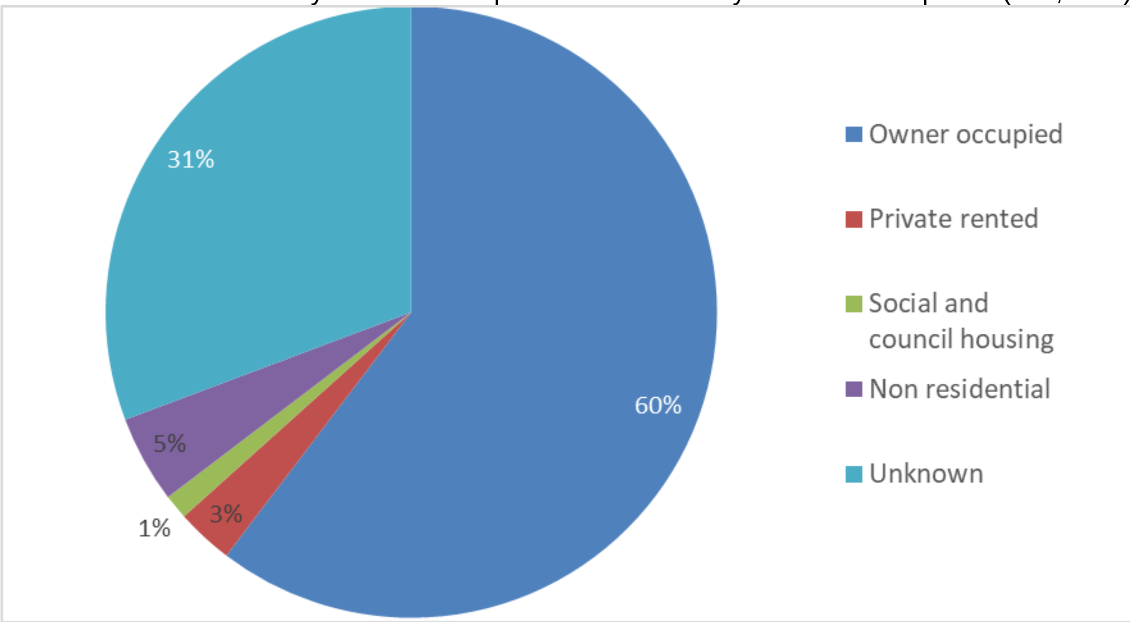

Figure 4: Percentage of installations by tenure

Table 1-6 summarise the potential solar PV resource by IRR band, from best to worst performing. They assume an average value of electricity generated of 16.5p/kWh and summarise the potential solar PV resource across each tenure and building use.

Table 1: Summary of total financially viable potential for rooftop solar PV installations in Georgeham Parish (all tenures and building types)

Potential lifetime IRR band (%)	Total installed MW potential (in IRR band)	Total generation potential GWh/yr	Number of Installations	Total capex (£k)
18-19%	0.11	0.10	1	90.42
17-18%	0.11	0.10	1	90.42
15-16%	0.98	0.96	248	1,001.30
14-15%	0.87	0.83	211	915.52
13-14%	1.14	1.04	234	1,215.38
12-13%	1.03	0.88	181	1,102.91
11-12%	0.29	0.24	59	310.59
10-11%	0.15	0.11	36	156.53
9-10%	0.07	0.05	19	70.92
8-9%	0.01	0.01	4	11.25
7-8%	0.01	0.00	2	6.48
Total	**4.74**	**4.32**	**996**	**4,971.72**

Table 2: Summary of owner occupied housing

Potential lifetime IRR band (%)	Total installed MW potential (in IRR band)	Total generation potential GWh/yr	Number of Installations	Total capex (£k)
18-19%	0.11	0.10	1	90.42
17-18%	0.63	0.64	187	665.21
15-16%	0.58	0.55	138	606.75
14-15%	0.41	0.37	111	430.75
13-14%	0.38	0.32	96	399.60
12-13%	0.09	0.07	26	99.12
11-12%	0.08	0.06	24	80.81
10-11%	0.05	0.03	14	53.53
9-10%	0.01	0.00	2	7.84
8-9%	0.01	0.00	2	6.48
7-8%	0.11	0.10	1	90.42
Total	**2.34**	**2.15**	**601**	**2,440.51**

Table 3: Summary of privately rented housing

Potential lifetime IRR band (%)	Total installed MW potential (in IRR band)	Total generation potential GWh/yr	Number of Installations	Total capex (£k)
15-16%	0.04	0.04	11	44.67
14-15%	0.02	0.02	6	20.46
13-14%	0.03	0.02	5	26.59
12-13%	0.01	0.01	4	14.32
11-12%	0.00	0.00	1	1.70
10-11%	0.01	0.00	2	6.82
9-10%	0.00	0.00	1	3.07
Total	**0.11**	**0.10**	**30**	**117.63**

Table 4: Summary of social and council housing

Potential lifetime IRR band (%)	Total installed MW potential (in IRR band)	Total generation potential GWh/yr	Number of Installations	Total capex (£k)
15-16%	0.02	0.02	5	21.48
13-14%	0.00	0.00	1	3.07
12-13%	0.02	0.02	6	19.78
9-10%	0.00	0.00	1	3.41
Total	**0.05**	**0.04**	**13**	**47.73**

Table 5: Summary of non-residential buildings

Potential lifetime IRR band (%)	Total installed MW potential (in IRR band)	Total generation potential GWh/yr	Number of Installations	Total capex (£k)
17-18%	0.11	0.10	1	90.42
15-16%	0.16	0.14	10	143.45
14-15%	0.04	0.04	11	44.36
13-14%	0.10	0.10	9	112.64
12-13%	0.13	0.11	12	136.82
11-12%	0.00	0.00	1	3.41
10-11%	0.00	0.00	1	3.07
8-9%	0.00	0.00	1	1.70
Total	**0.54**	**0.49**	**46**	**535.87**

Table 6: Summary of unknown tenure

Potential lifetime IRR band (%)	Total installed MW potential (in IRR band)	Total generation potential GWh/yr	Number of Installations	Total capex (£k)
15-16%	0.12	0.12	35	126.49
14-15%	0.23	0.22	56	243.96
13-14%	0.60	0.55	108	642.33
12-13%	0.49	0.43	63	532.40
11-12%	0.19	0.16	31	206.36
10-11%	0.06	0.05	9	65.84
9-10%	0.01	0.01	3	10.91
8-9%	0.00	0.00	1	1.70
Total	**1.70**	**1.53**	**306**	**1,829.98**

3.6 Carbon Emissions

In 2020 domestic electricity users in the parish consumed 5,612,901 kWh. This equates to carbon emissions of 1,192 tonnes of CO2e (using a grid electricity carbon emissions factor[3]). Figure 5 and Figure 6 show the impact on carbon emissions of installing all of the potential solar PV within the parish (with the 16.5p/kWh assumption for the value of the generated electricity). Figure 5 prioritises the roofs with the highest kWh generation and Figure 6 starts with the highest internal rate of return. The end result in both is decarbonising the domestic electricity demand by 77% (leaving domestic electricity emissions at 275 tonnes CO2e).

Figure 7 and Figure 8 show the same as above but for the scenario with an electricity value of 28p/kWh and with a £4k battery fixed cost. The result once all PV is installed on all roofs (996 installations) shows net negative emissions as all domestic electricity within the parish is covered by the solar PV. However, in practice, there would be more generation in summer and less in winter, and with a higher demand in winter. Domestic batteries wouldn't be able to store enough in summer to provide power all through the winter, so it is likely that grid electricity would still be used in winter.

If solar PV is installed at a rate of 100 installations per year, it will take 10 years to reduce the emissions to the end point in all of the graphs below. However, this assumes that the variables remain consistent (no change in electricity demand from the 2020 baseline, grid electricity emission factor stays the same, and that generation meets demand year-round). If 125 installations were made per year, the parish PV rollout will take 8 years to complete.

[3] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

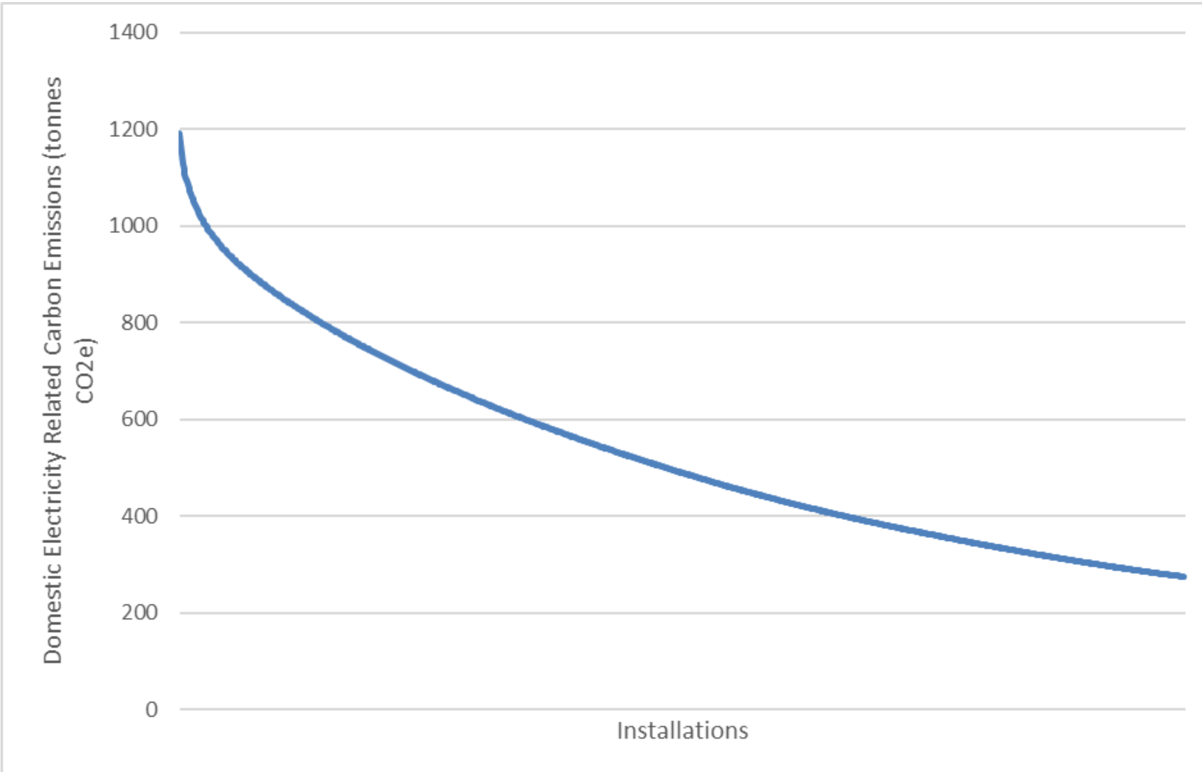

Figure 5: Domestic electricity decarbonisation rate with highest potential kWh solar PV generation (at value of 16.5p/kWh)

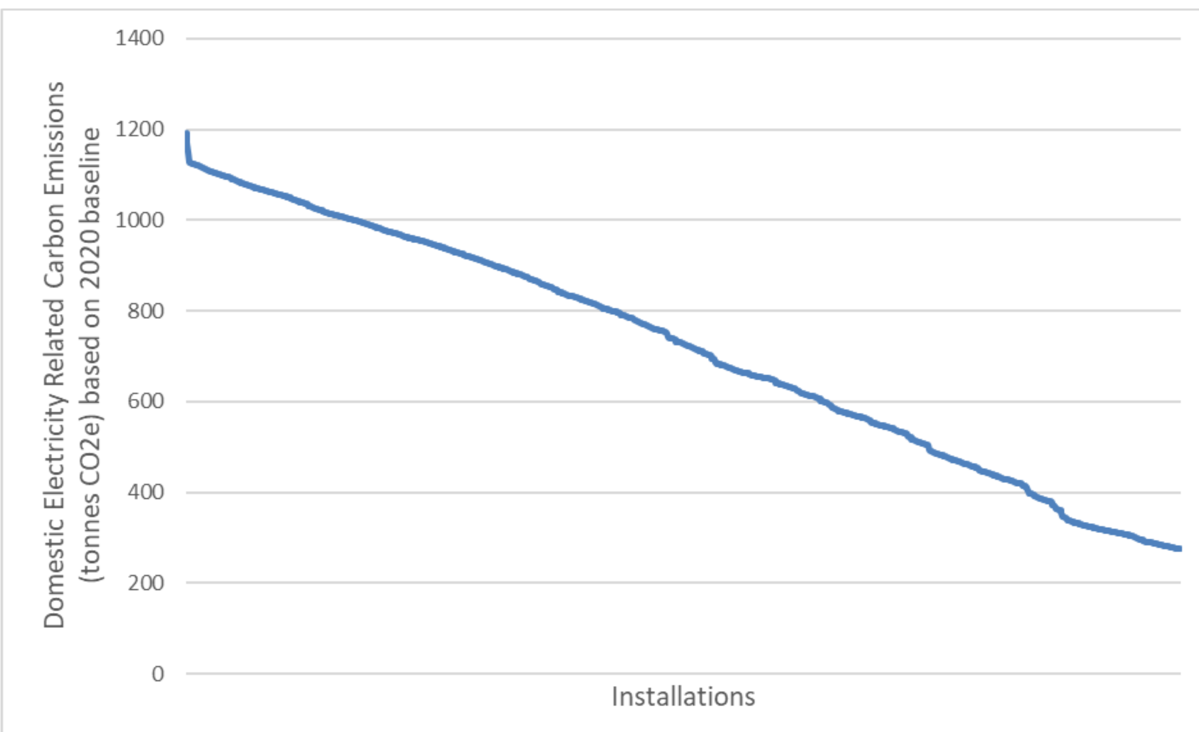

Figure 6: Domestic electricity decarbonisation rate when rolling out by highest IRR band (at value of 16.5p/kWh)

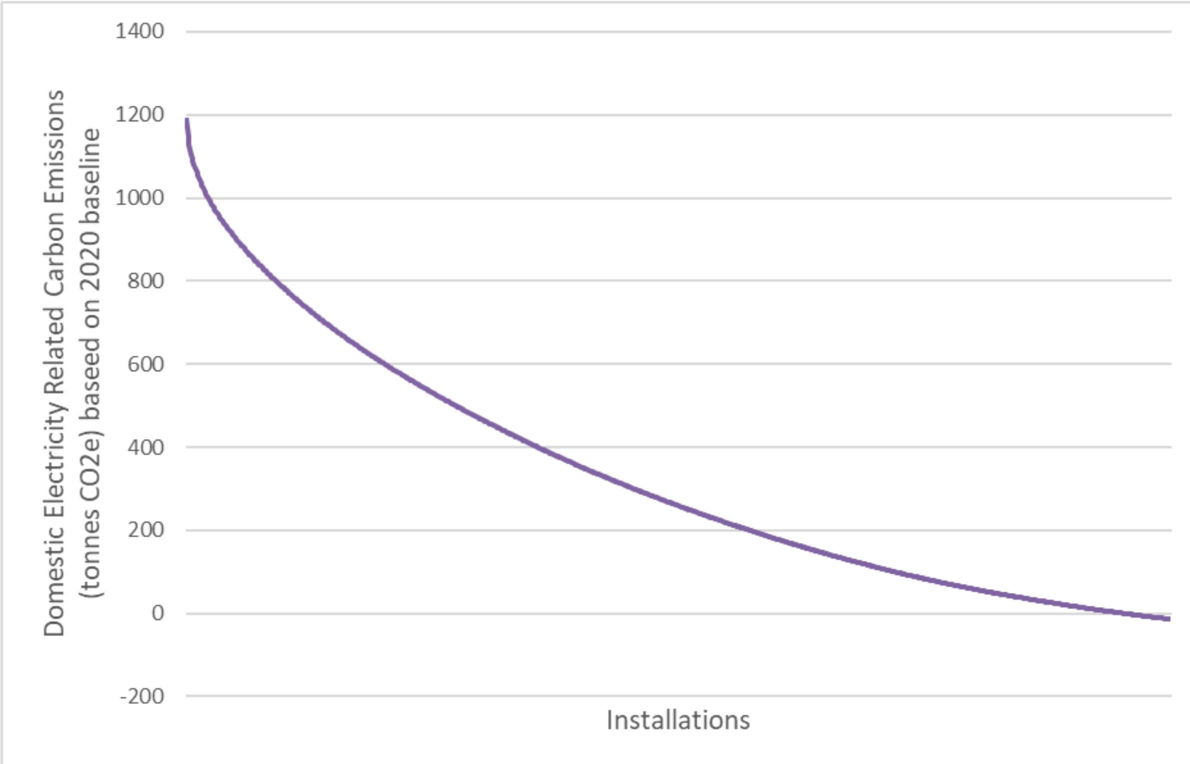

Figure 7: Domestic electricity decarbonisation rate with highest potential kWh solar PV generation (at value of 28p/kWh and with a £4k battery)

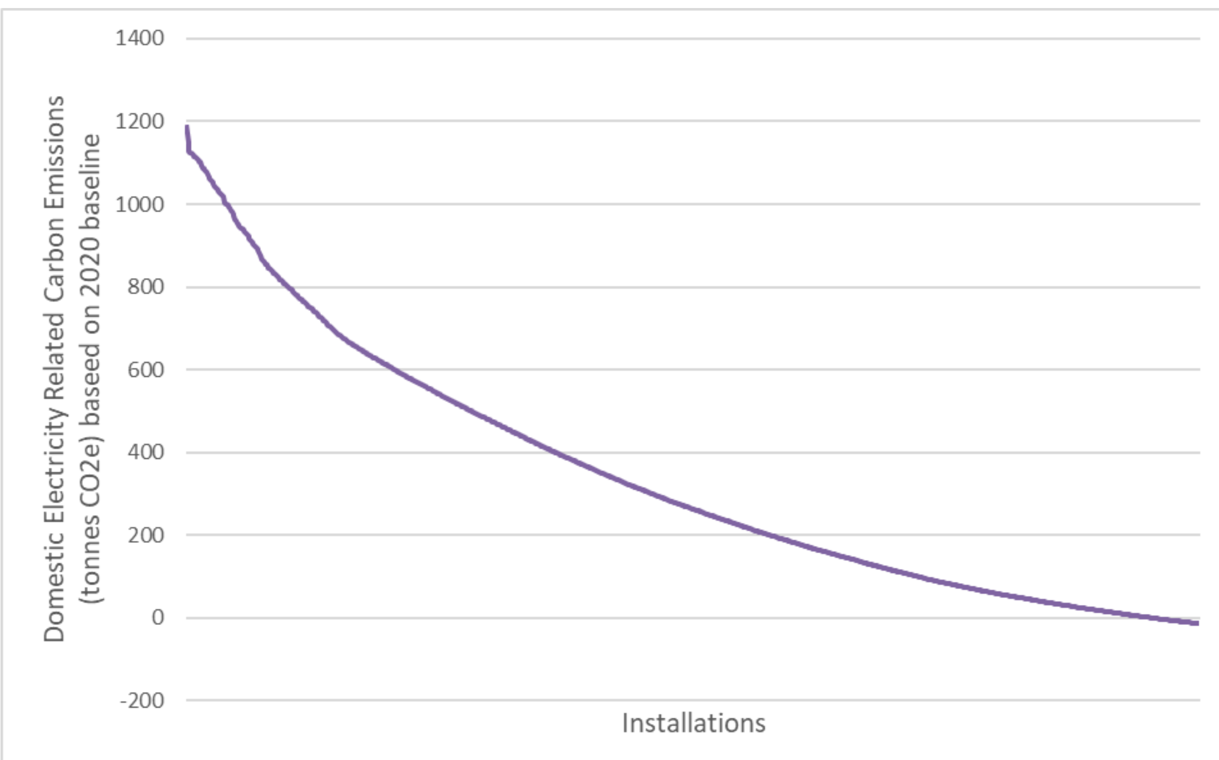

Figure 8: Domestic electricity decarbonisation rate when rolling out by highest IRR band (at value of 28p/kWh and with a £4k battery)

4 Appendix

4.1 Albion's Cost Benefit Assumptions

Solar PV model requirements	Model Inputs
Period	25 years
Discount rate	0.035
Costs of electricity £/kWh	0.165 and 0.28
0-10 kWp: £ per kWp for installation	1,000
10-100 kWp: £ per kWp for installation	922
kWp >100: £ for installation	714
Fixed cost £	0 and 4,000 (battery)
0-10 kWp VAT rate	0.05
10-100 kWp VAT rate	0.2
kWp >100 VAT rate	0.2
Excludes buildings that already have a PV installation and listed buildings	TRUE

4.2 Other Outputs

As part of this project the following outputs have been created alongside this report:

File Name	File Type	Description
16.5p-by-address	.xlsx (Microsoft Excel Spreadsheet)	Spreadsheet with building addresses (and their modelled panels) per row
28p-4k-battery-by-address	.xlsx (Microsoft Excel Spreadsheet)	Spreadsheet with building addresses (and their modelled panels) per row
16.5p-by-IRR-tenure	.xlsx (Microsoft Excel Spreadsheet)	Spreadsheet with tables grouping panels by IRR as Tables 1-6 above
28p-4k-battery-by-IRR-tenure	.xlsx (Microsoft Excel Spreadsheet)	Spreadsheet with tables grouping panels by IRR as Tables 1-6 above
Has-solar-PV	.xlsx (Microsoft Excel Spreadsheet)	Spreadsheet with addresses that already have solar PV
16.5p	.gpkg (GeoPackage file for use within GIS)	Geographical data showing the solar PV panels shapes
28p-4k-battery	.gpkg (GeoPackage file for use within GIS)	Geographical data showing the solar PV panels shapes
Georgeham-OS-Buildings	.gpkg (GeoPackage file for use within GIS)	Geographical data showing the building outlines (from Ordnance Survey)
Croyde-solar-PV-panels	.png (image file)	A map of Croyde showing panels on buildings
Heat-map-solar-with-OSM-basemap	PDF	A heat map showing the solar potential – weighted by annual generation with an OpenStreetMap basemap
Solar-pv-panels-buildings-red-with-OSM-basemap	PDF	A map of the parish showing panels and building outlines with an OpenStreetMap basemap.