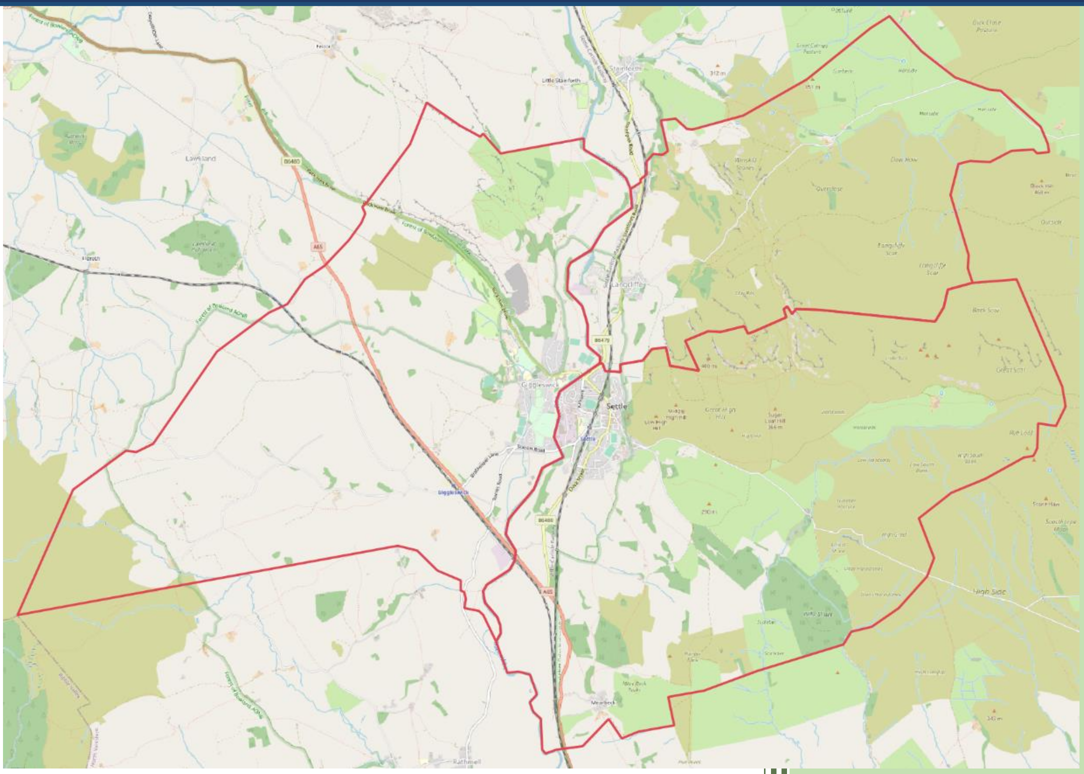
# Mapping Potential Roof Spaces Suitable for Solar Power Generation in Settle, Giggleswick and Langcliffe



**Dr Tom Nicholls**
**Software Developer**
CodeClass Ltd

**Funded by: Action on Climate Emergency Settle and Area**

**Sarah Wiltshire**
**ACE Settle Co-ordinator**
*Email*: acesettleandarea@gmail.com

**CodeClass Ltd:**

**Dr Tom Nicholls**
**Software Developer**
CodeClass Ltd,
www.codeclass.co.uk
*E-mail:* tom@codeclass.co.uk

# Contents

# 1. Introduction and Quick Summary of Results

## 1.1. ACE Settle and Area

ACE Settle and Area is a community group covering Settle and its surrounding area, which was set-up in March 2019 to take practical action and to campaign for a just transition to a sustainable net zero carbon world locally, nationally and internationally. As part of this work ACE has four themed groups, including an Energy Group, to act as a focal point for identifying and involving the local community in taking practical action on these key themes. The Energy Group produced a Local Area Energy Plan, after consultation with the local community, in December 2022 detailing the potential for more renewable energy generation locally across the electricity substation area of Settle, Giggleswick and Langcliffe. This included the proposal to significantly increase the amount of solar pv on domestic, community and commercial properties. The report and detailed information on the map will be a key element in planning and implementing a significant uptake of solar PV over the whole project area, making efficient use of installation resources and maximizing the area's potential for solar power generation.

## 1.2. Project Background

This project grew out of an earlier research project at Lancaster University (and funded by Cumbria Action for Sustainability) to identify the potential for solar installation on building roofs for Ambleside.

Cumbria Action for Sustainability (CAfS) is a charitable organisation with the goal of supporting a zero carbon Cumbria. The organisation supports sustainability in Cumbria communities and businesses via various projects. CAfS are currently working with various local communities in Cumbria to develop a plan for a zero carbon footprint for each community.

A manual methodology was developed by Alex Boyd at Lancaster University in conjunction with CAfS in order to determine which roofs might be theoretically able to support solar PV installation, using two publicly available data sources. A further project between the University and CAfS, in order to turn the process into a repeatable computer algorithm, was completed by Dr Tom Nicholls. This algorithm has now been applied to further communities in Cumbria and the rural north, the results for one of which – Settle – are described here.

The project aims to utilise 3D satellite imagery to identify flat roof spaces inside the local community boundary. The methodology then eliminates roof spaces that are too small to support solar, those that are oriented the wrong way (e.g., north-facing roofs) and those that are calculated to be in shadow - from other buildings, structures and hills - for too much of the year.

## 1.3. Quick Summary of Results

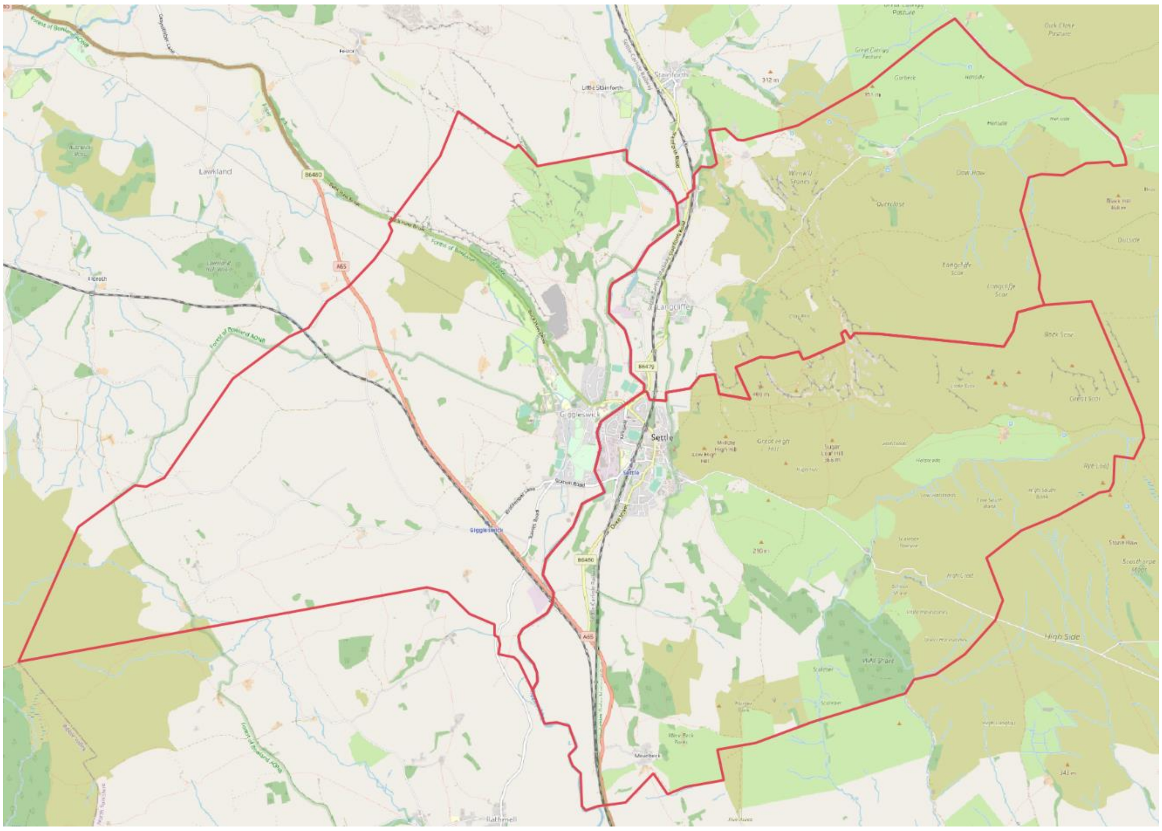
Within the parish boundaries of Settle, Giggleswick and Langcliffe, there are 1481 buildings in the Ordnance Survey open data set. From these buildings, the algorithm was able to identify 2126 roof spaces that might be suitable for solar (with many roof spaces occupying the same buildings). The total estimated solar potential for the area as a whole is 11.7 Gigawatt-Hours (GWh). A web map is available at the following address to view the results: http://acesettleandarea.org/settlemap/ . A spreadsheet with further detail on each estimated roof area has also been made available to the community.

# 2. The Algorithm

## 2.1. How the Algorithm Works

The “algorithm” is simply a set of mathematical calculations performed on two sets of geographic data (which can be considered to be two different maps of the same area). The calculations can be thought of as a complex mathematical formula and are performed in the open-source software “QGIS”. They are written in the programming language Python and are run as a set of plugins.

The user is invited to create a border around their local community on a map. The map below shows the Parish boundaries for the three areas as defined by the Office of National Statistics in 2019.



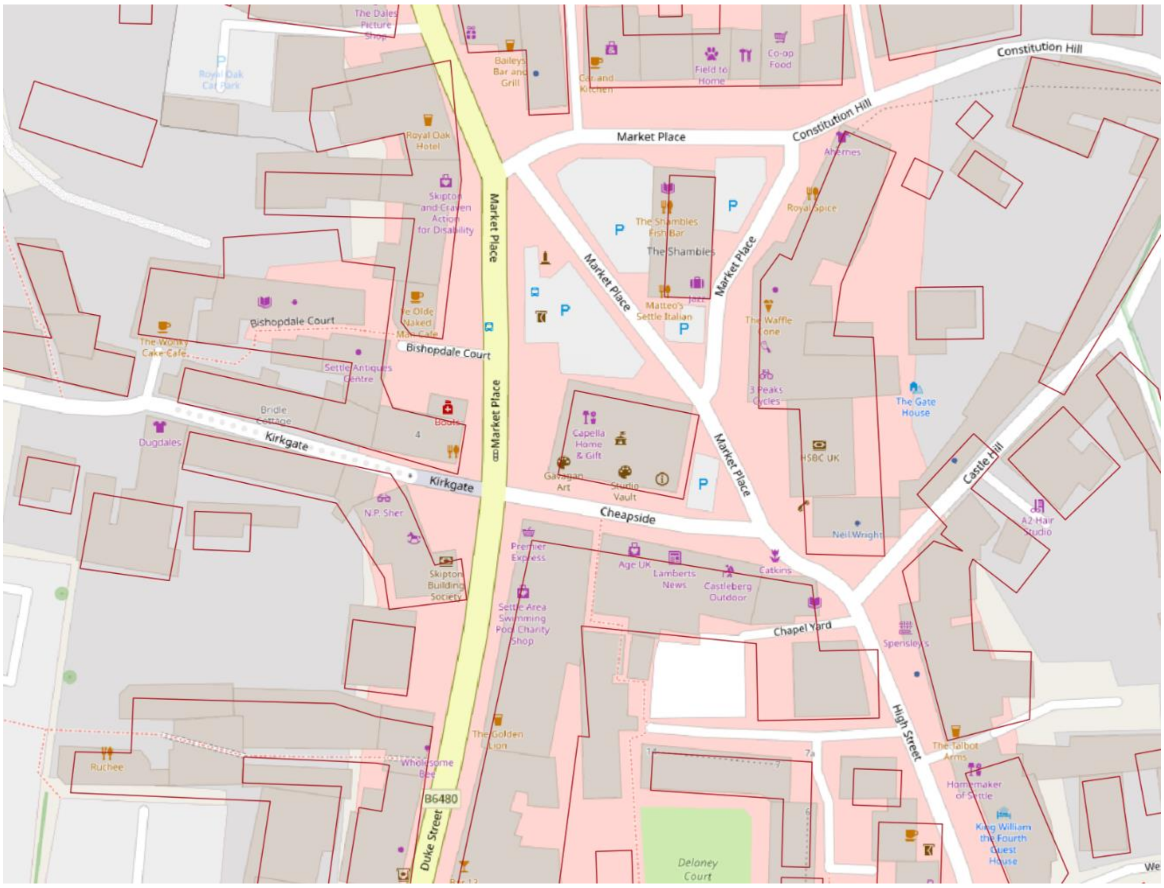
The algorithm then attempts to identify roof spaces which are suitably located and oriented in order to receive sufficient sunlight to be good candidates for solar panels.

## 2.2. The Data Sets

Two sets of publicly available data are used in the calculation, described here.

### 2.2.1. Ordnance Survey Buildings Data

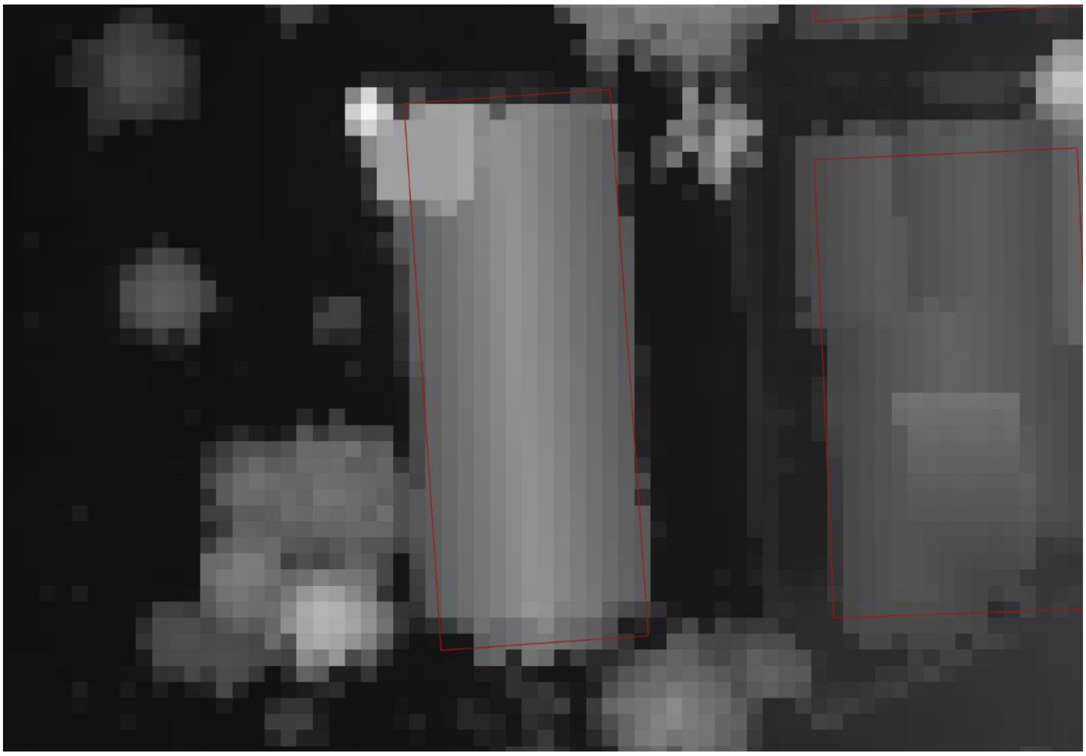
Ordnance Survey open data (from January 2023) is used to locate the outline of each candidate building in the target area (1481 in total). These are shown in red in the following map of the centre of Settle.



### 2.2.2. LiDAR Data

"LiDAR" data is 3-dimensional data which shows the height of the landscape itself, buildings, vegetation, and other structures above sea level at a resolution of 1-metre.

LiDAR, somewhat analogous to radar, is the process of using laser light to estimate the 3D form of a landscape (or other target). In our case, the department for environment, Defra, has flown planes over most of the UK to obtain LiDAR data in the form of height data above the ground (note that the data used in the project from the winter of 2022/23). This is shown in black and white for the area around Settle Parish Church in the following figure:




Higher regions are shown as lighter areas and it is possible to see the shapes of buildings above the ground and even infer their roof shapes from a visual inspection. For example, the church tower is visible to the north of the map area, with the spire as the highest point.  The roof ridge is also clearly visible, with roof slopes on either side (approximately to the east and west).

Immediately below the LiDAR map is a screenshot from Google Satellite View from the same area.  It is striking how trees and other vegetation become obvious in the LiDAR view once seen alongside this overhead photograph.

A 3D model constructed using this data is perhaps more revealing.  This first view is a wide area view looking over the town centre from the South.  High Fell is visible to the right and Giggleswick Scar and Quarry also clearly visible to the left to the rear of the view.

The second is from the area around Settle Parish Church once again, this time from the north.  In this second image reconstruction I have projected the ESRI satellite image into 3D using the LiDAR data.  The shape of the church, surrounding buildings, and – importantly – surrounding obstructions such as vegetation are clearly visible.  It is obvious that some of the larger trees will be capable of casting shadows over certain buildings.

The algorithm uses this data to reconstruct roof shapes and to estimate which roof areas will receive sufficient sunlight throughout the year in order to be suitable for solar PV installation.

## 2.3. Stages in the Algorithm

There are four stages in the algorithm, each of which comprises many individual calculations:

i) The algorithm tries to locate flat areas on building roofs which are considered not to be obstructed by chimneys etc. For example, on a simple residential building roof this might be two rectangular areas on opposite sides of the roof sloping downwards. On most (real) buildings this would be more complex, with chimneys, dormer windows and smaller slopes obstructing potential sites for solar panels.

ii) The algorithm uses geometry to calculate the shadow falling on each of these areas at four different times of the year and discards those that are deemed to be in too much shadow.

iii) The algorithm discards those roof areas that are considered too small to support a minimum of 6 solar panels (smaller than 16 square metres) and those whose direction is not suitable for solar PV (e.g., north facing roofs).

iv) The algorithm then uses geometry and historical weather conditions to calculate the amount of sunlight falling on each roof, how many solar panels might be fitted there, and the resulting solar energy theoretically generated from that roof over the course of a year.

## 2.4. Roof Elimination Strategy

A typical solar panel as an area between 1.65 and 1.75 $m^2$

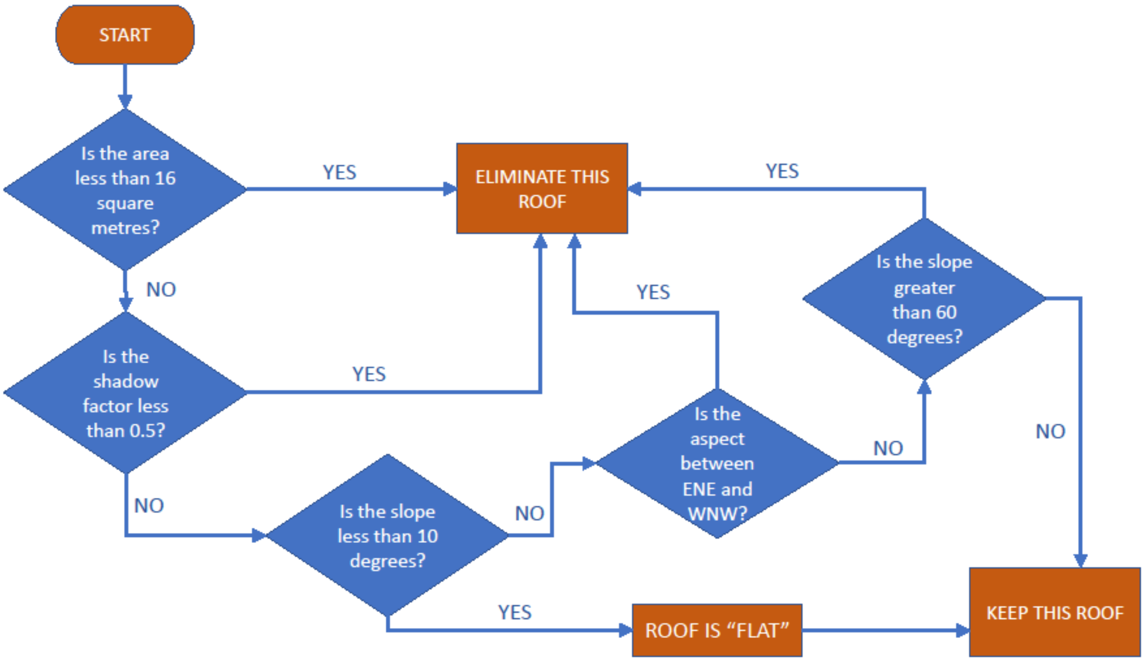
When interviewed, a group of solar installers said that they considered a 2kW array to be the smallest viable, which is 6 panels of the above size, typically.

By the time you factor in a border and the fact that panels need to be oriented in rectangles, the minimum area needed for an installation can be calculated to be 16 $m^2$ and this is the figure used in our calculations.

It should be noted that some other installers will work with 1kW arrays, and this is indeed seen for some smaller installations in Cumbria.

Installers will also not consider roofs that have a slope (or "pitch") of more than 60 degrees. When the slope is smaller than 10 degrees, we consider this roof to be "flat and suitable for panels to be installed on supports at an angle of 15 degrees. We also eliminate roofs between ENE and WNW that have a northerly aspect and so are pointed away from the path of the sun. This angle of elimination is in total 135 degrees.

A flowchart of the complete elimination process is shown below:



# 3. Results

## 3.1. Location of Web Map

The web map is publicly available at the following address:

http://acesettleandarea.org/settlemap/

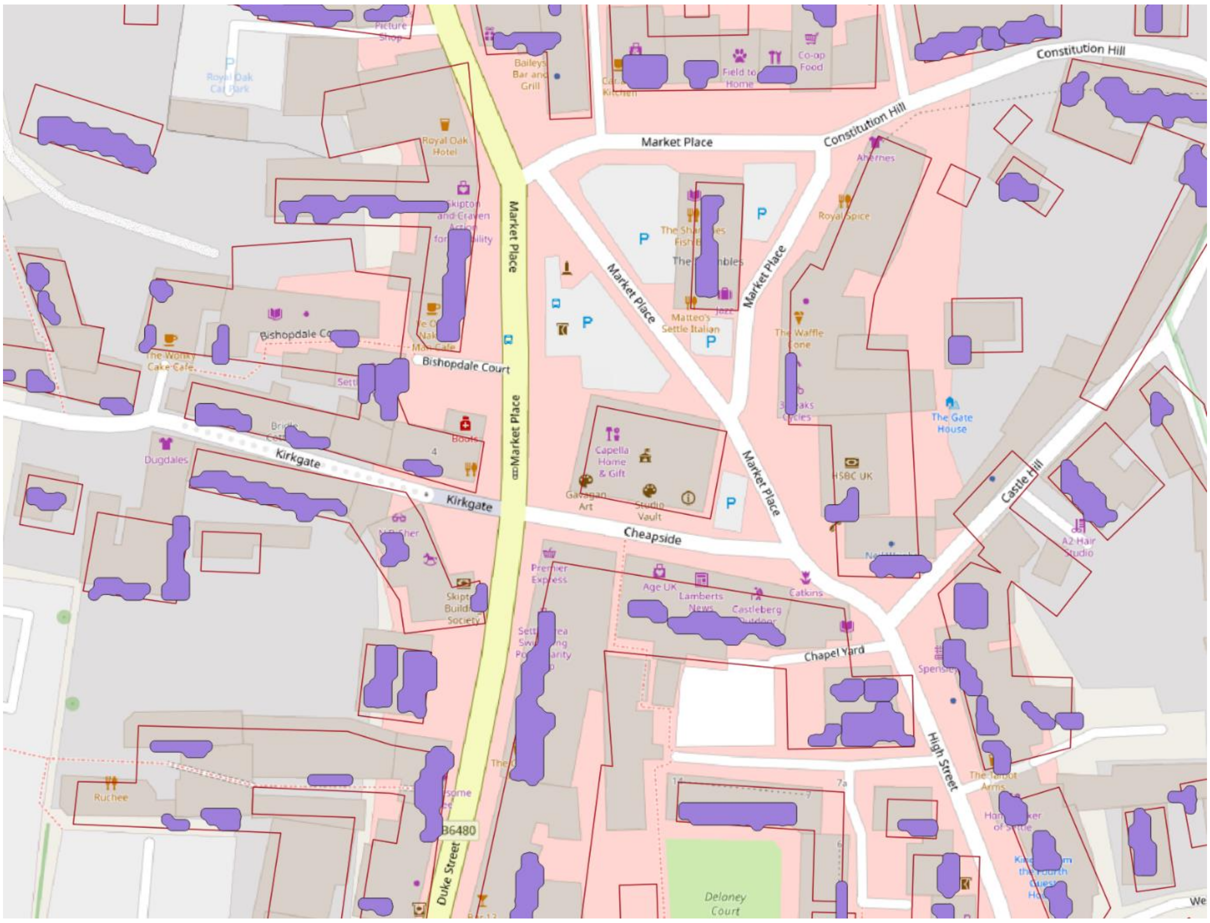
## 3.2. Description of Map Areas

### 3.2.1. Open Street Map

The Settle map (roads, rivers, buildings, features etc) is derived from the OpenStreetMap online mapping service (openstreetmap.org), which is open source and free to use.

### 3.2.2. Suitable Roofs

The lilac areas on the map show where the algorithm has found flat areas which are considered suitable for solar panels. By hovering over each area with a mouse, it is possible to see the following details for that roof area: latitude and longitude (which are in ordnance survey coordinates and are also known as northings and eastings); number of solar panels which might be fitted there; the total energy output in kWh that those panels might be expected to produce; an "id" identifier number which numbers each roof area and cross-references with the spreadsheet.




Roof areas are ordered so that the smallest id number "1" relates to the roof with the highest potential for solar power generation. So, we see that the roof area with biggest potential for solar PV is a section of the roof of *** ******* (there are also other potential roof spaces on this building).

### 3.2.3. Navigating the Web Map and Using the Search Functions

Some quick search tips are given below:

- A quick way of zooming in and out of the map on a desktop is to use a mouse wheel.
- Roof areas are ordered by id number: roof number 1 is the roof that has been calculated to produce the biggest power output etc
- By moving the mouse pointer over a roof area, summary details can be viewed - id number, OS map coordinates (northings and eastings) and solar output of that roof area.
- The map itself is based on open source OpenStreetMap data.

### 3.2.4. Parish Boundary

The Settle Parish boundary line is shown in red on the map.

### 3.2.5. Building Outlines

Ordnance Survey building outlines are shown in dark red.

### 3.2.6. Searching Functions

Below is a quick example (albeit from a different area) of how to cross reference "id" numbers with roof locations on the web map. It also demonstrates how to quickly view the characteristics of a particular roof.

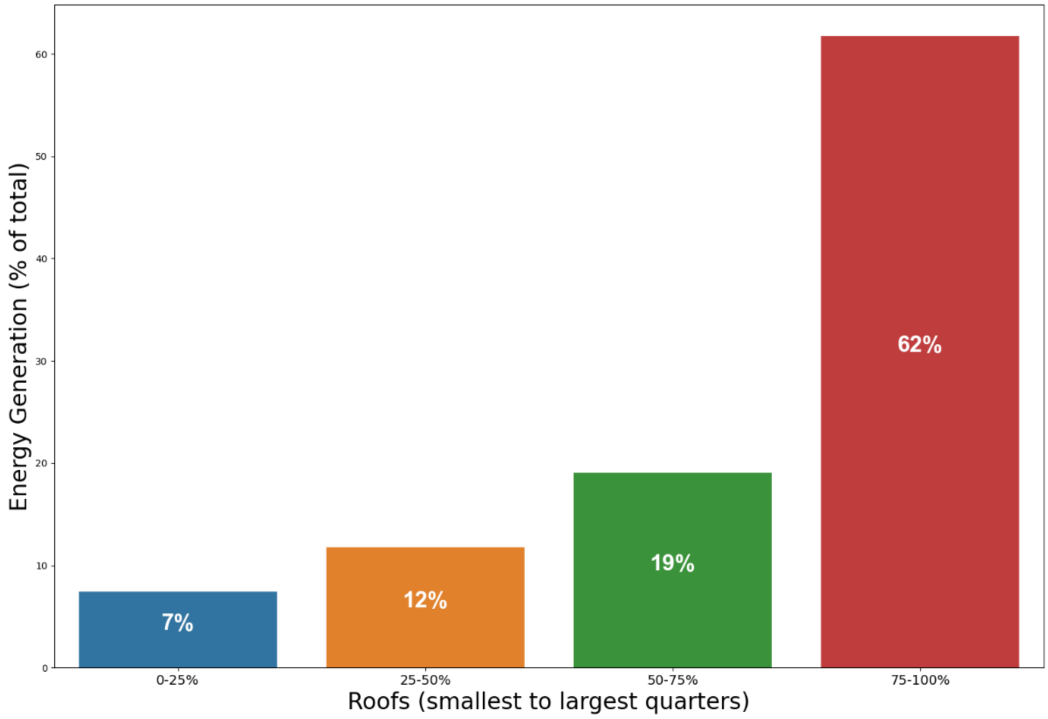

## 3.3. Spreadsheet

A spreadsheet is available which shows technical details of each suitable roof area. As well as the values which are shown in the map, the estimated area of each roof is shown, whether the roof is flat and the "shading factor", which is an estimate of how much light passes through each year and is not affected by shadows from other buildings, structures, vegetation and hills.

From the spreadsheet we see a total roof area of 128,000 square metres available for siting of solar panels on a total of 2216 individual roof areas. These together are estimated to produce 11.7 GWh of electricity annually if all installations were to be completed.

## 3.4. Focusing on Larger Roofs

An analysis of the estimated suitable roofs finds that the largest 25% of roof spaces could be responsible for generating 62% of the solar power for Settle. This is shown in the graph below, where roof spaces are divided up by size into four quarters (i.e., the smallest quarter of roofs up to the largest quarter). This suggests that by prioritising the larger roofs, a larger proportion of the power needs of Settle can be met.




# 4. Challenges and Limitations

There are a number of limitations to the model, as described below.

## 4.1. The data is far from perfect

The LiDAR data is itself an estimation of building height etc above the ground based on laser measurements. Not only is there a small amount of noise in the data, but there are also artefacts introduced from the LiDAR mapping process itself. For these reasons we believe that the algorithm misses some areas that might well be valid (because it can see obstructions in flat roofs where there are none) and so the overall figure for potential solar electricity generation is probably quite conservative.

## 4.2. The data is low resolution

The LiDAR data is available at 1 metre resolution for much of the rural north (meaning that data points are spaced on a 1 metre square grid). In many other parts of the UK the resolution is much higher (50 or even 25cm) which means 4 or 16 times as many points in the data grid and much more detail to work from. This improves the chances of finding chimneys and other obstructions and means that noise is less important in these other areas.

## 4.3. This is only a model

The computer model is not the real thing, and so cannot predict real life with full accuracy.

## 4.4. Limitations in the Mapping

Unfortunately, it has not been possible to find a straightforward way to map the roof spaces with the corresponding street addresses at this time, so this step currently needs to be performed manually.

# 5. Evidence Base

## 5.1. Limitations of the Model

It is important to note that this method is relatively new and therefore untested; the communities in Ambleside, Keswick, Alston Moor, Halton-With-Aughton, Kendal, Levens, Ulverston, Penrith, Greysouthern, the Duddon Valley and Arnside have been testing the results of the model ahead of the Settle community.

In the report for the original Ambleside pilot project, Alex Boyd, the originator of the process, has attempted a comparison between some of the variables found by the algorithm and those estimated using Google maps satellite and street view imagery. the area, slope and aspect of a random sample of 20 roofs in the set of "suitable roofs" and found there to be a strong match between theory and reality.

While the shadow calculation has not been tested against reality, we believe it to be a more thorough calculation than most manual estimates.

Because of the novel nature of this algorithm, the solar mapping provided to the communities in Settle et al represent the first real world test of this method.

Some anecdotal evidence tentatively supporting the results of the algorithm has been presented in the form of feedback from the community group *Sustainable Keswick* whose members have been attempting to compare predictions of the algorithm in Keswick with real power generation statistics from the area. In general, they are finding a close relationship between predicted and actual findings. A couple of observations from this work are of note:

i) The minimum viable solar installation of 2kW may be too high, in that smaller installations are seen in the area (note that one scientific paper in the literature which proposes a similar methodology assumes a minimum cut-off of 1kW).

ii) Often the LiDAR estimates are too high because not all of the available roof area is used for the installation, either by choice or by some structural or geometrical limitation of the roof itself.

Please contact CAfS for further information as to the progress of other communities in evaluating the model.

# 6. How to Interpret the Results

It is very important to note the limitations in the model and **to not treat the results of this algorithm as a replacement for a manual solar PV survey**.

This method will not find all roofs suitable for solar panel installation, so there will certainly be roofs that already have solar installed which are discounted as candidate roofs.

We believe that the algorithm is probably quite conservative in finding roofs; as a result, we would expect the total available roof space actually to be bigger than predicted.

However, this model is beneficial as a useful starting point for an entire community. It will find many suitable roofs and reduce the cost and manual effort of locating roofs. It will also enable communities to invest in bulk buying schemes, for example.

# 7. References

## 7.1. Original Method

The original process for Ambleside, as created by Alex Boyd, can be described in the following paper available from CAfS:

*"Mapping Solar PV Potential in Ambleside"* (joint report between CAfS and Lancaster University, 9th December 2019)

It should be noted that a further step, to estimate the shadow effects of distant mountains, has been added since the original method was published.

## 7.2. LiDAR Data

Data is available from:
https://environment.data.gov.uk/DefraDataDownload/?Mode=survey

It is necessary to download two data sources for each area of interest: the DSM and the DTM.

## 7.3. Meteorological year data

This data, which is necessary to calculate the solar radiation to estimate power generation of potential suitable roofs, is available from here:
https://re.jrc.ec.europa.eu/tmy.html

## 7.4. Ordnance Survey Buildings Data

The open data from Ordnance Survey which includes building outlines is available from here:
https://www.ordnancesurvey.co.uk/opendatadownload/products.html#OPMPLC