Hochschule für Technik Stuttgart
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Geographic Information System – GIS
GIS Practice
Suitability for Photovoltaic-Solar Panels and 3D City Model from Lidar Data
Pro. Dr. Dietrich Schröder

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1. Generating Digital Elevation Model and Digital Surface Model from Lidar Data

To generate the DSM, the ground points and the height points from the building were combined in one shapefile, but first a previous selection of the points was performed. A buffer of the buildings to avoid noise between these two sources was performed.

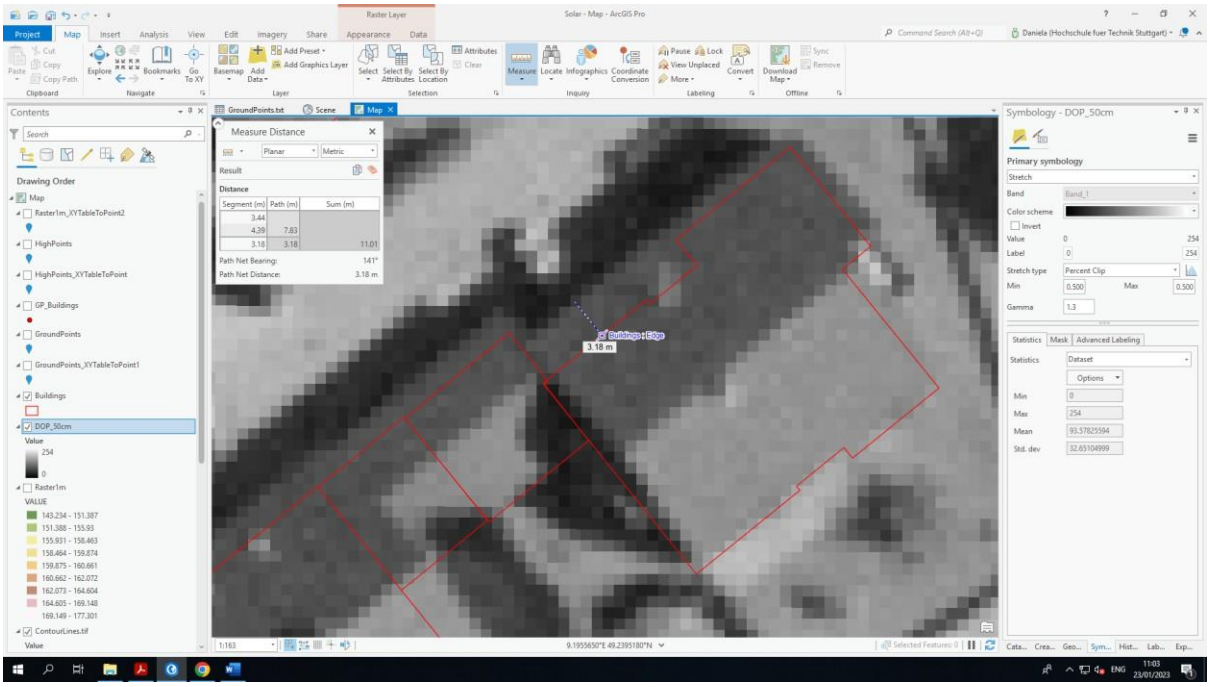

Figure 1 The Digital Orthophoto overlaid with building footprint

A buffer of 1 meter was created around the buildings and a selection by location for separate the points from the two sources was done for approximating the roof.

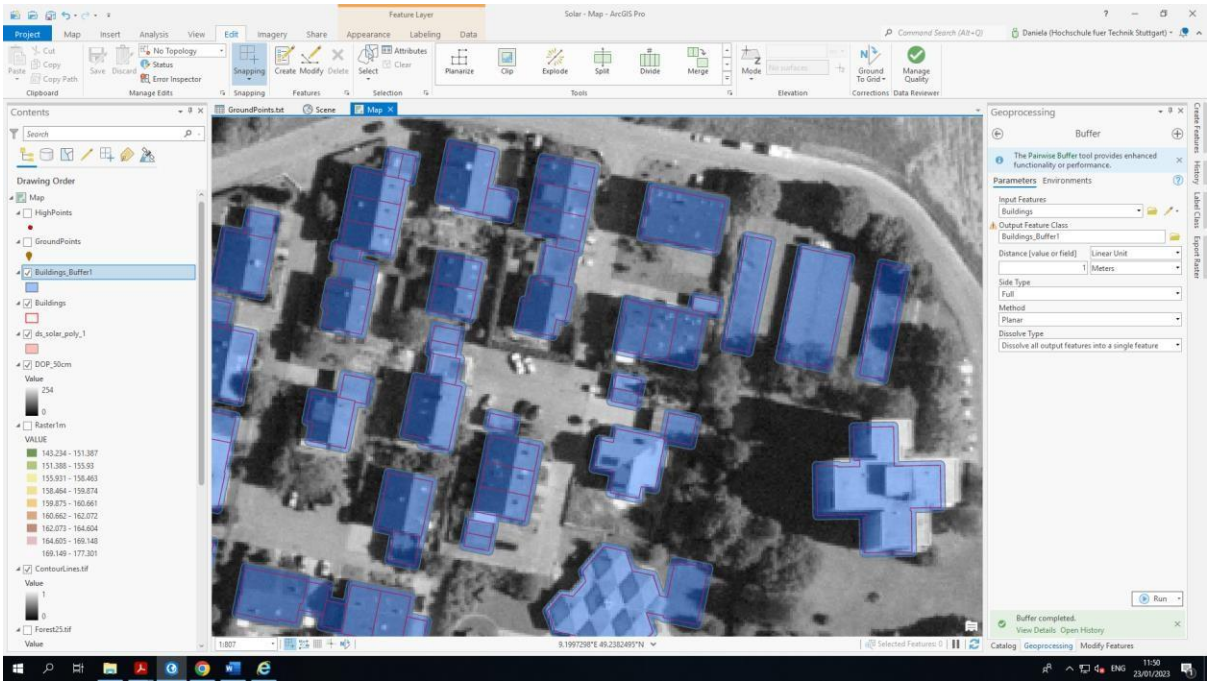

Figure 2 one meter Buffer of the building

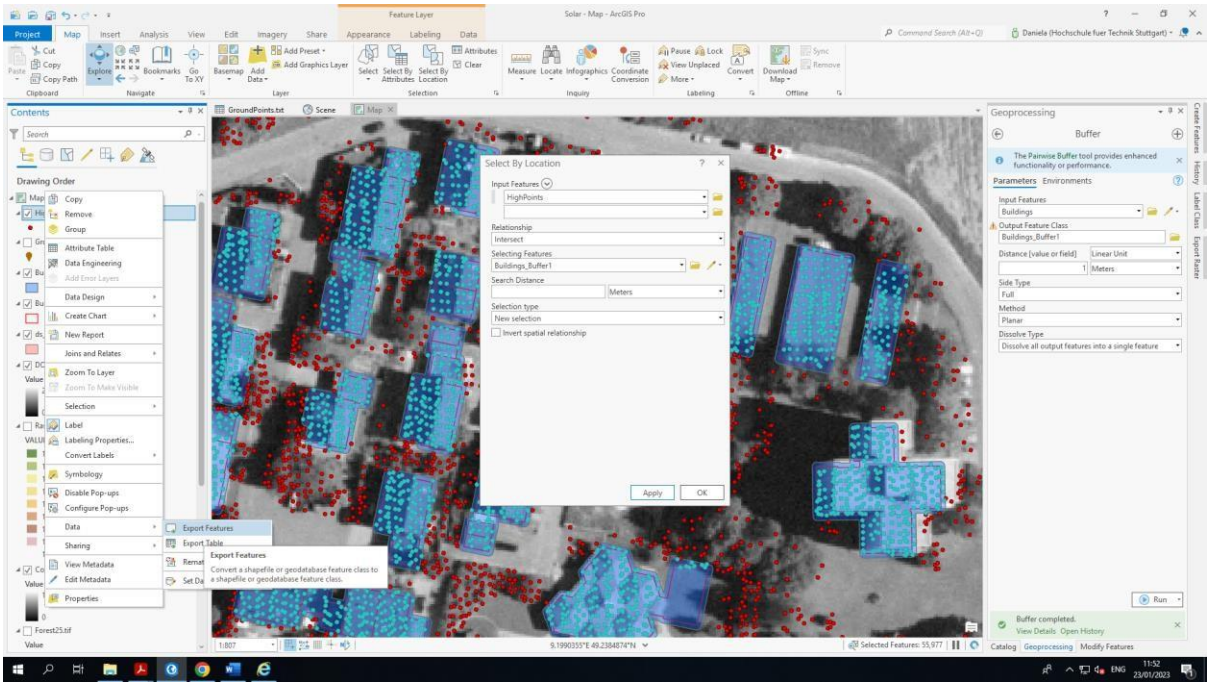

Figure 3 selecting height point inside the building

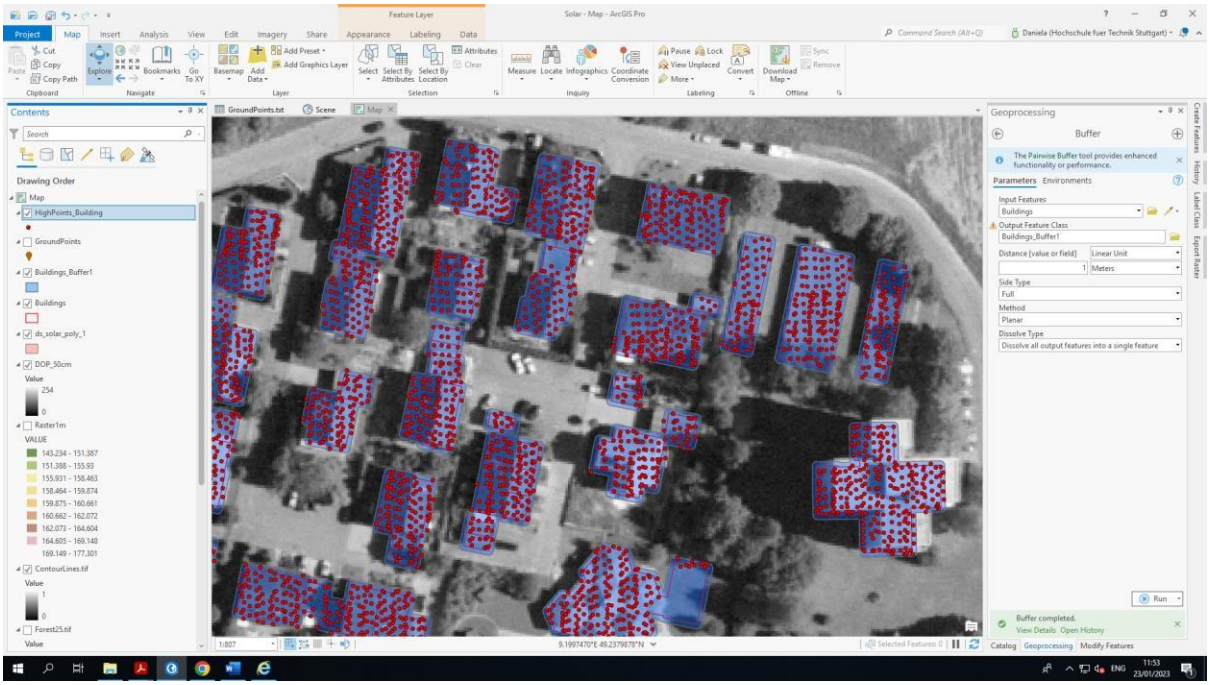

Figure 4 Height Points only in on Building

Once the points are organized in just one file, avoiding different height for the same location, a interpolation of the area is performed.

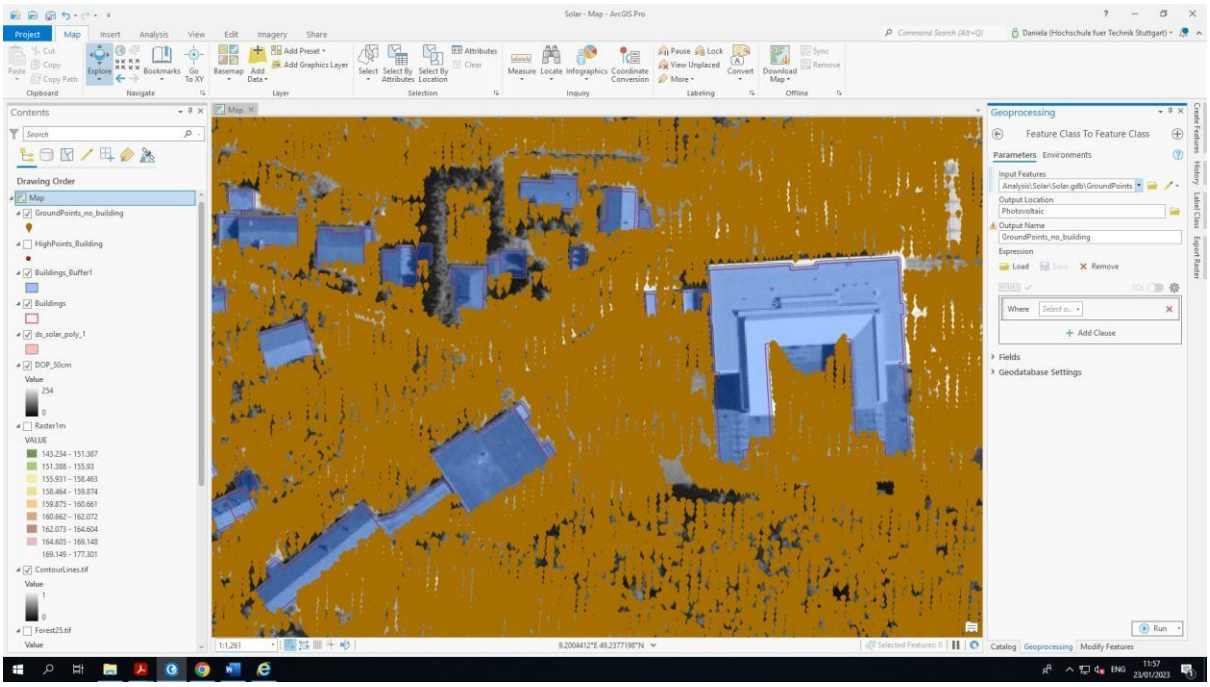

Figure 5 Ground Point only on Ground

The best suitable interpolation method found was ‘Spline with Barriers’, because it allows the addition of a boundary, like the buffer building, what would improve the interpolation result for the building area.

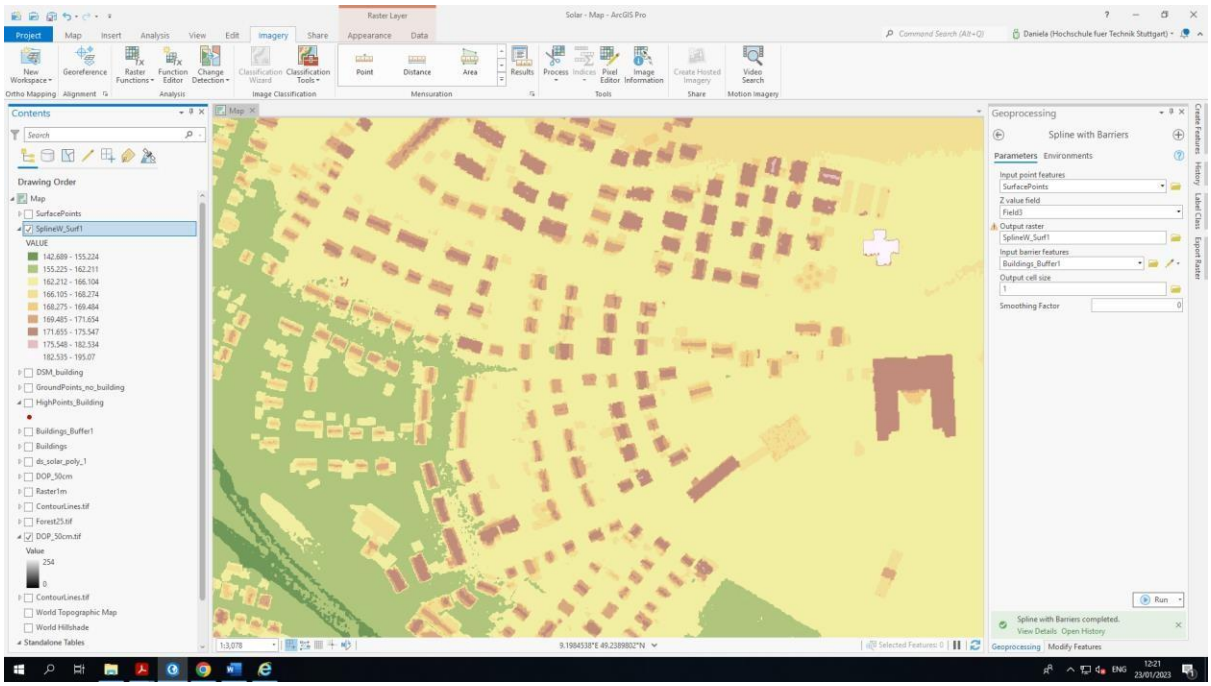

Figure 6 Result of spline with barrier interpolation

A DEM was also created with the ground points. The tool used was Topo to Raster.

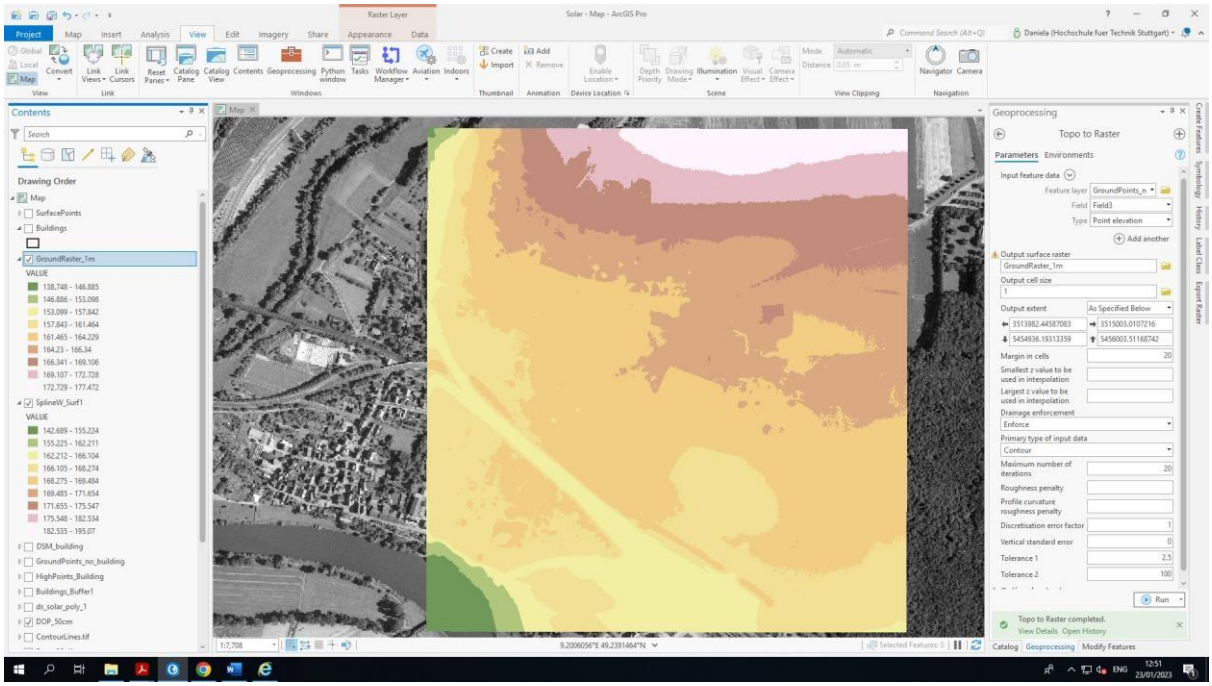

Figure 7 Result of DEM from ground height point

To calculate the height of the buildings Raster Calculator was used, making a subtraction between the interpolation of the surface and the DEM.

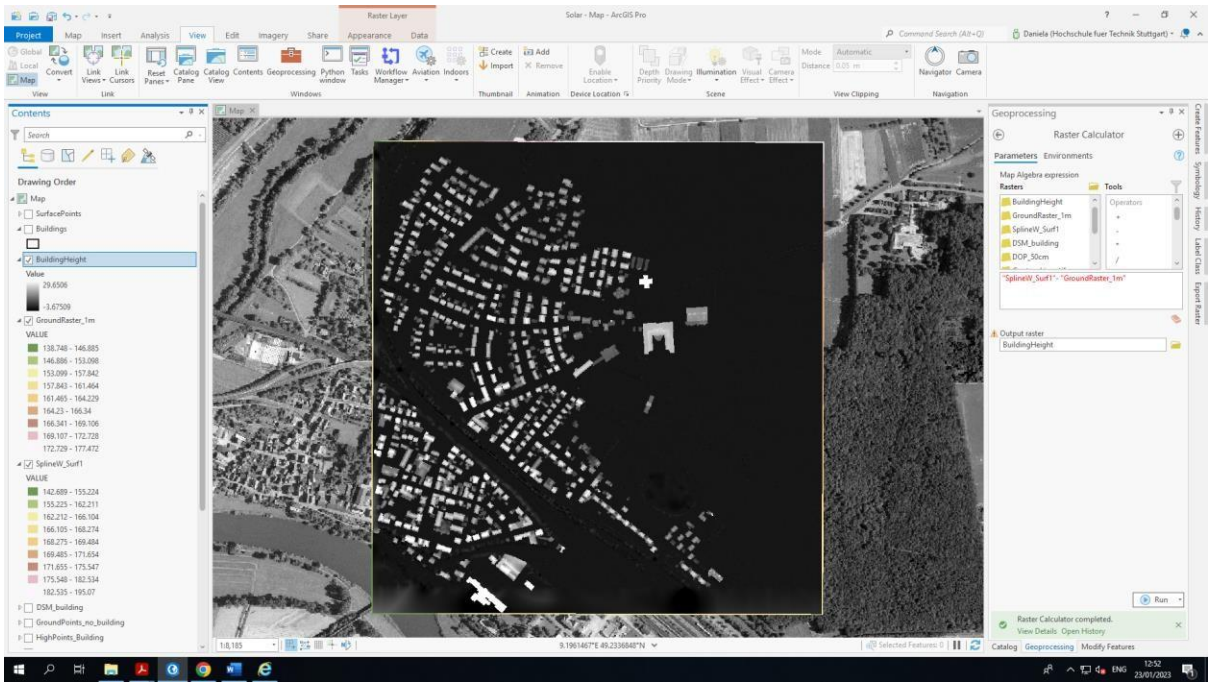

Figure 8 Raster of Building height from subtracting spline interpolation and DEM

2. Suitability Analysis of the rooftop for Solar Energy

2.1. Suitability from Slope and Aspect

The slope was calculated with the raster of the surface.

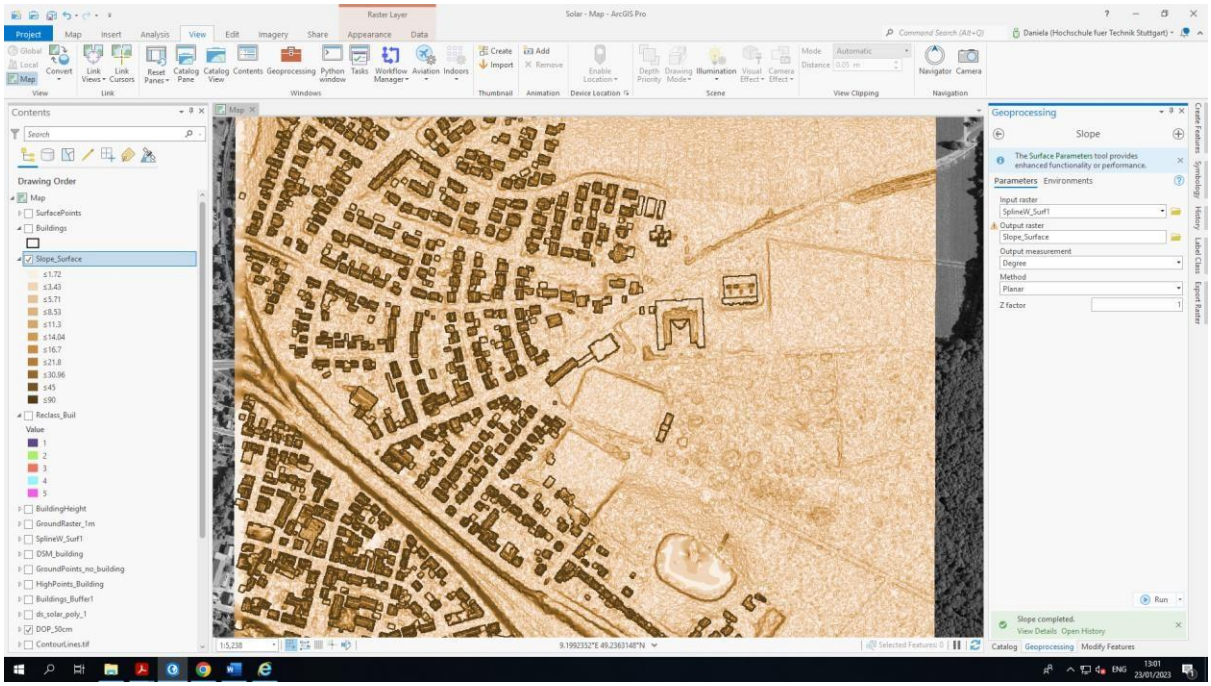

Figure 9 surface slope

A reclassify of the slope was performed according with the suitability of the slope for the solar panels. The smaller the value of slope the best calcification for suitability the category receives. The slope values between 0 and 10 are considered flat, so this category receives the higher score, 5. All the values over 60 are considered no suitable, so they receive a value of 0.

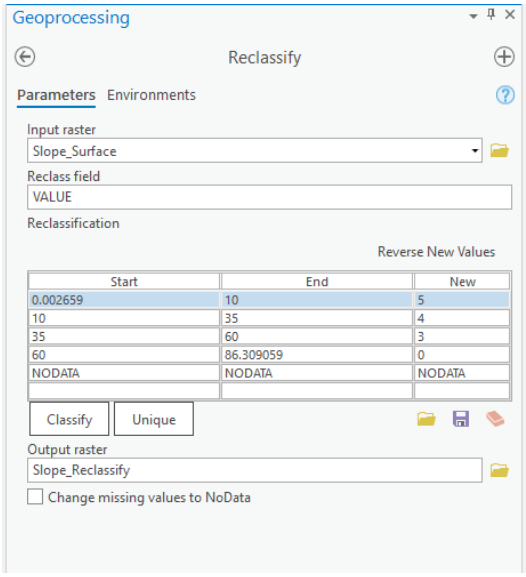

Figure 10 reclassification parameter of slope surface

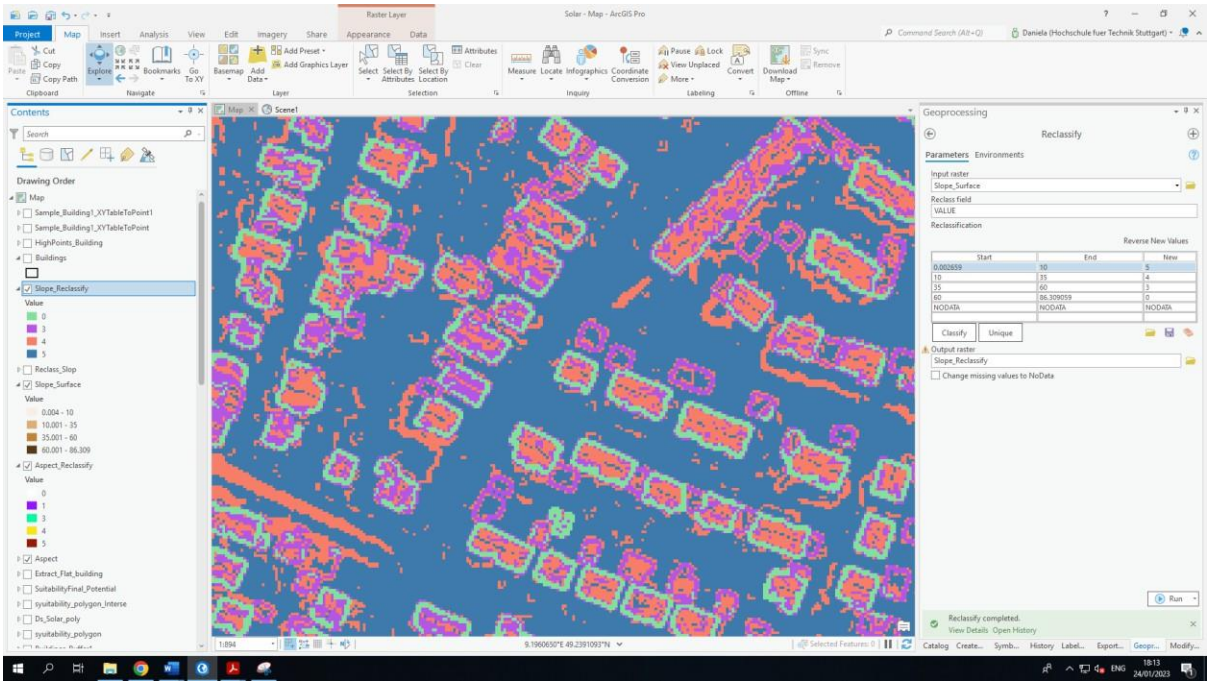

Figure 11 reclassification of slope surface

The aspect was also generated with the surface raster.

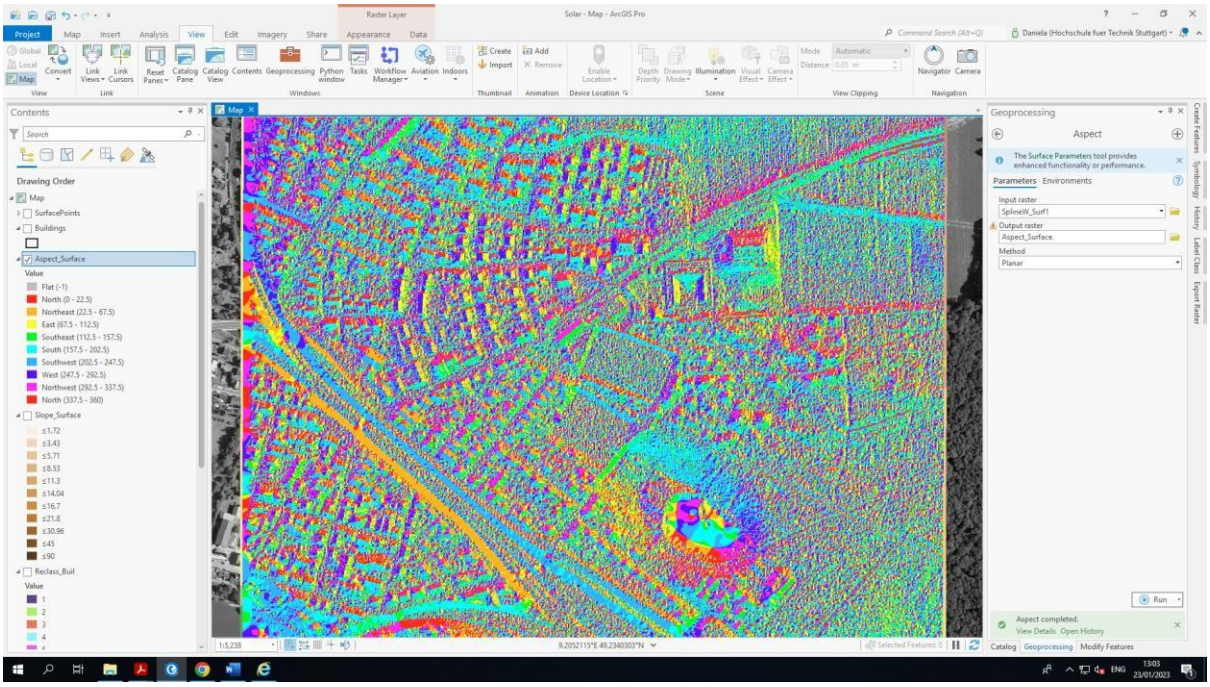

Figure 12 Surface Aspect to define the direction of the surface

A Reclassify was also performed, according to the suitability for solar panels. The values that correspond to north direction receive the smallest score, in the contrary, the values of the south areas received the highest values.

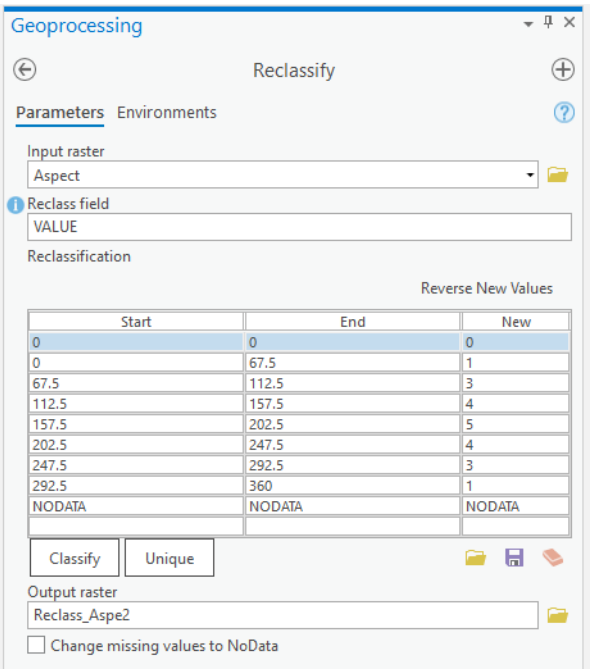

Figure 13 Aspect classification parameters

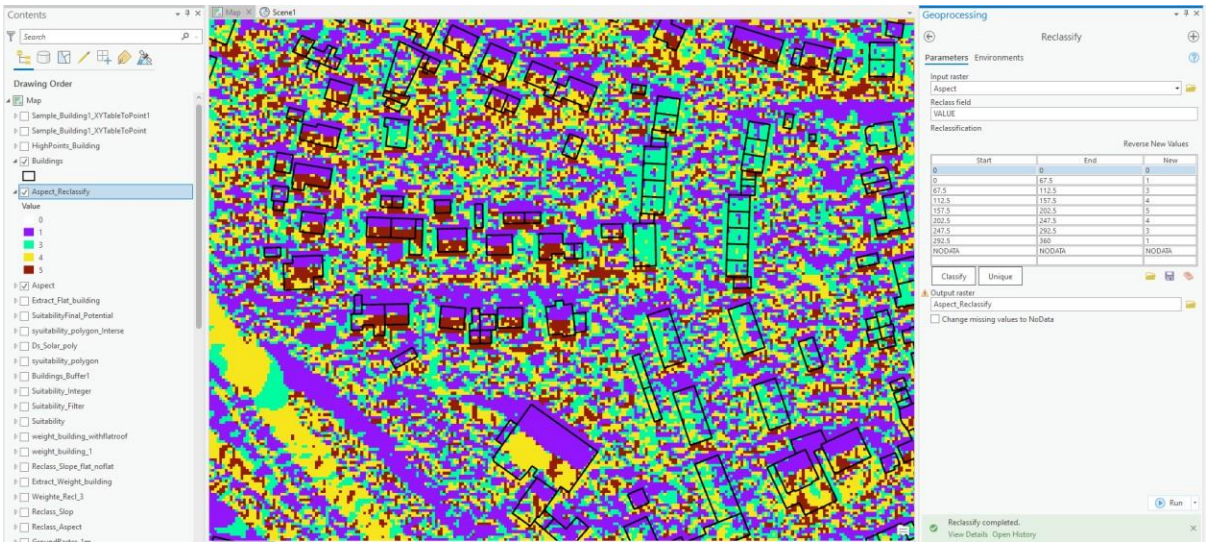

Figure 14 Aspect value after reclassified

The aspect does not affect the buildings with flat roof, for that reason, a reclassification was performed to separate these two categories, and can be used the flat area to assign the higher score regardless of the aspect.

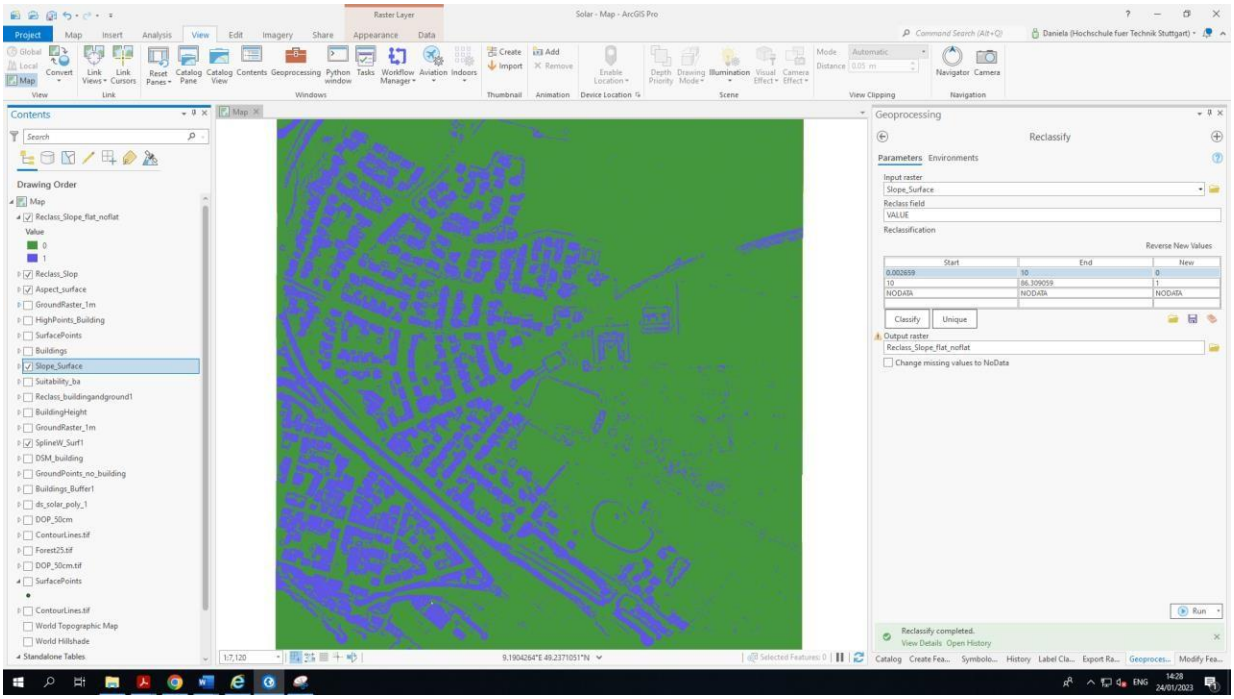

Figure 15 Determination of building with flat roof and non-flat roof

The tool ‘Weighted Overlay’ was used to classify the areas according to the slope and aspect.

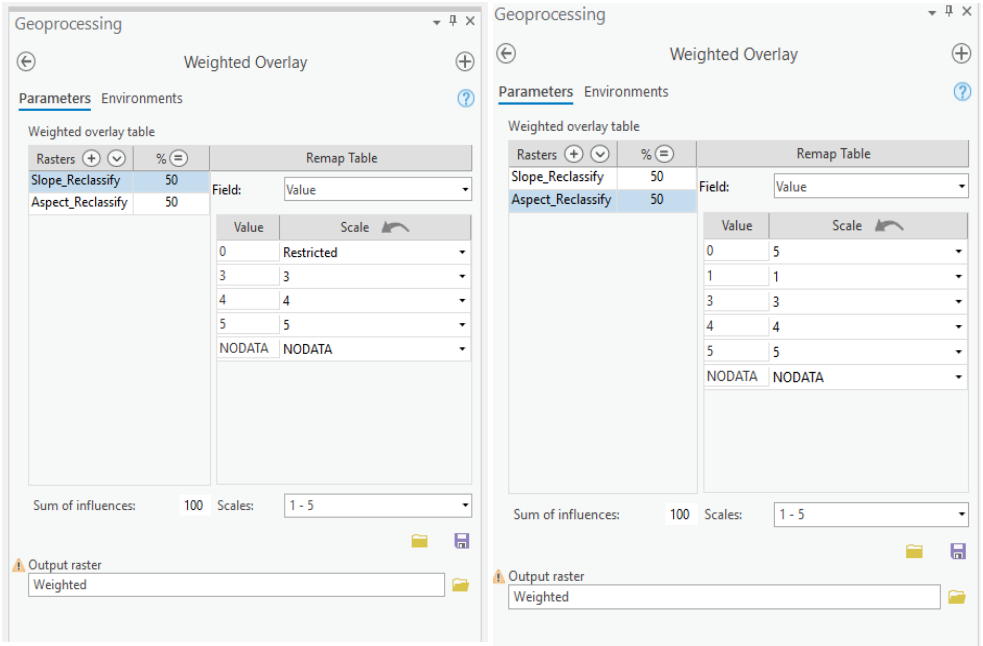

Figure 16 Weighted overlay parameters

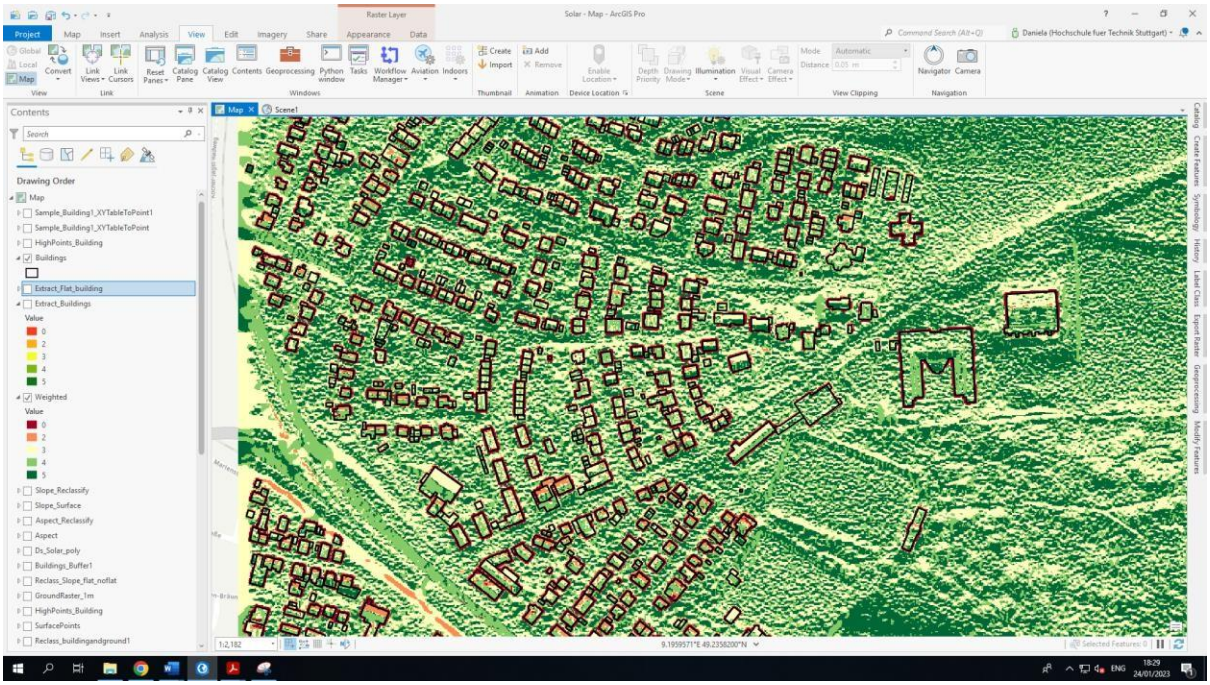

Figure 17 Weighted overlay result as suitability area map

To have the information of only the buildings, the tool ‘Extract by mask’ is used.

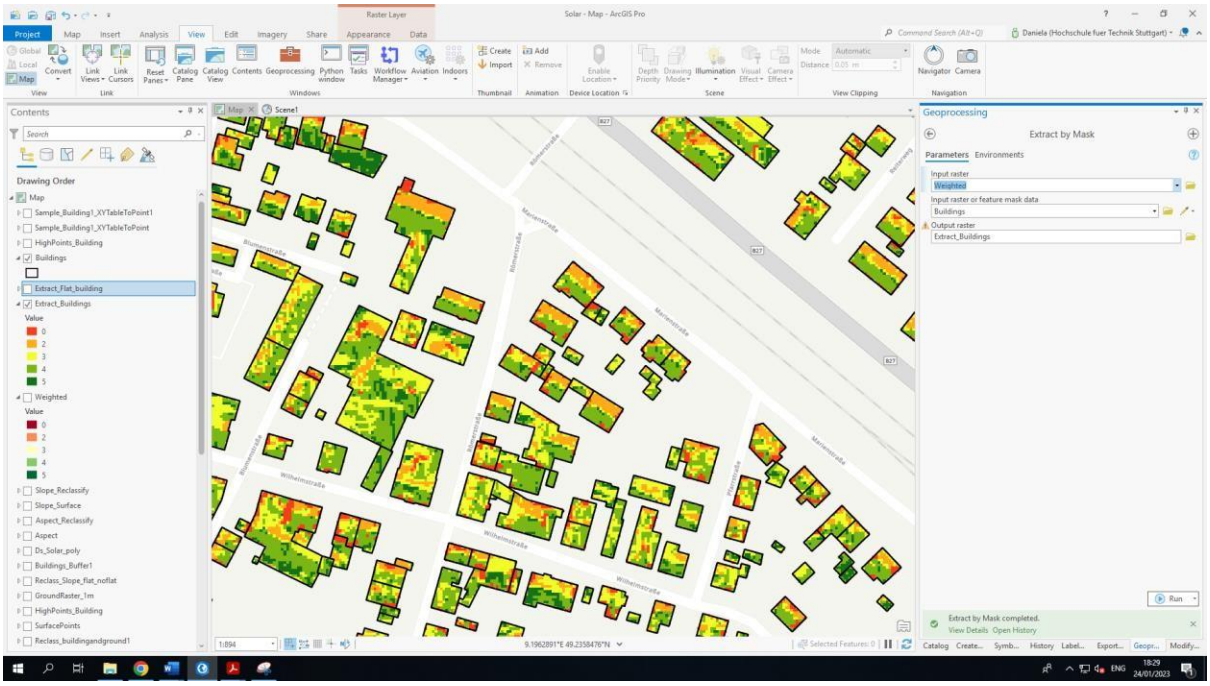

Figure 18 suitability map only on roof

The raster generated previously, with the flat roof category, is used to differentiate these areas and assign the highest value (5) to this area.

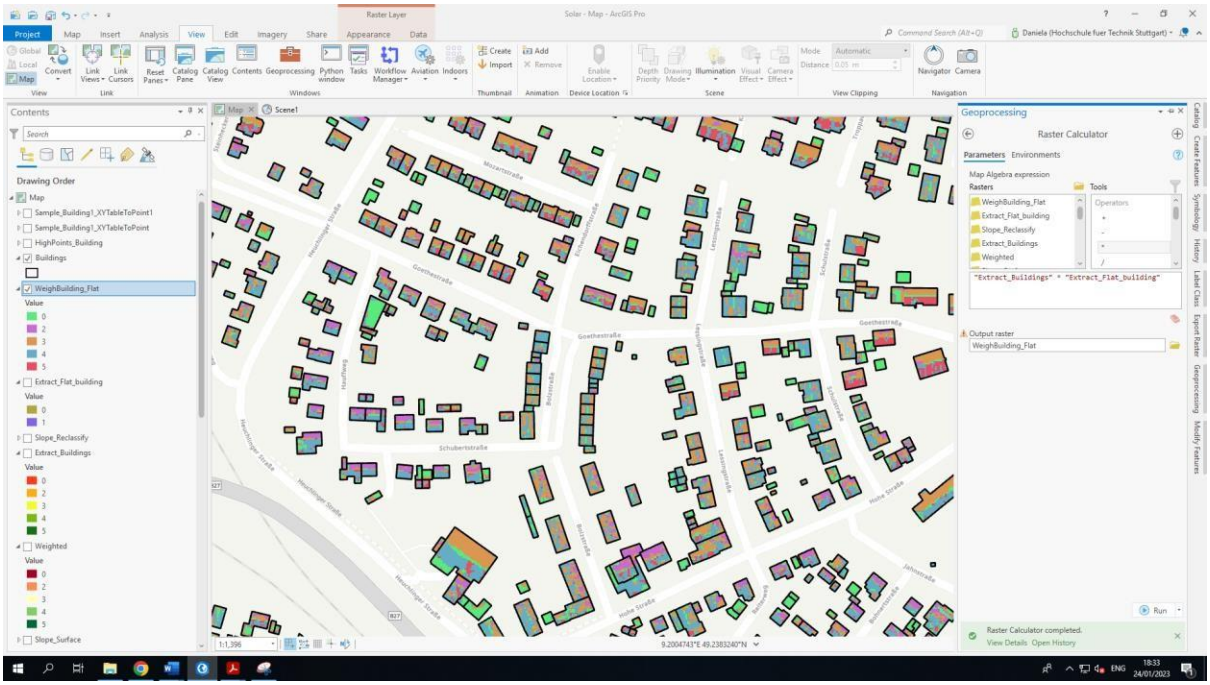

Figure 19 Merging the suitability map with flat roof

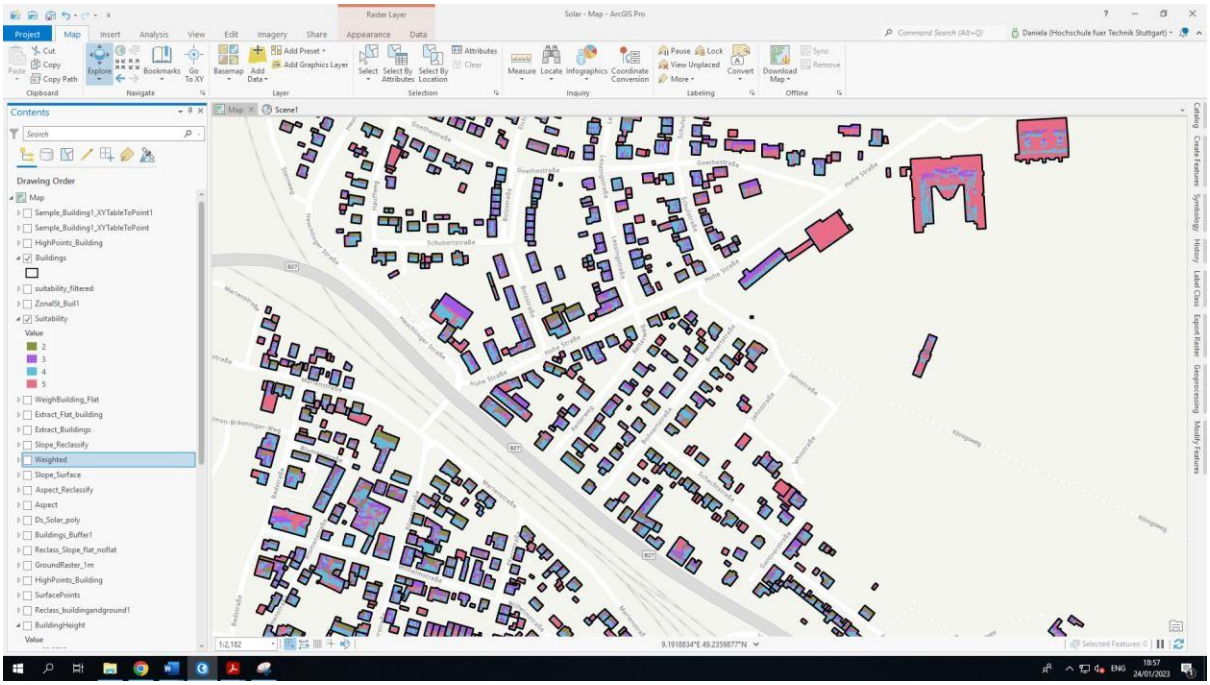

Figure 20 Suitability map with considering the flat roof as most suitable area

To avoid noise in the categories of the roof, a filter is used. The low pass filter helps to eliminate small areas by combining the value with the surrounding pixels.

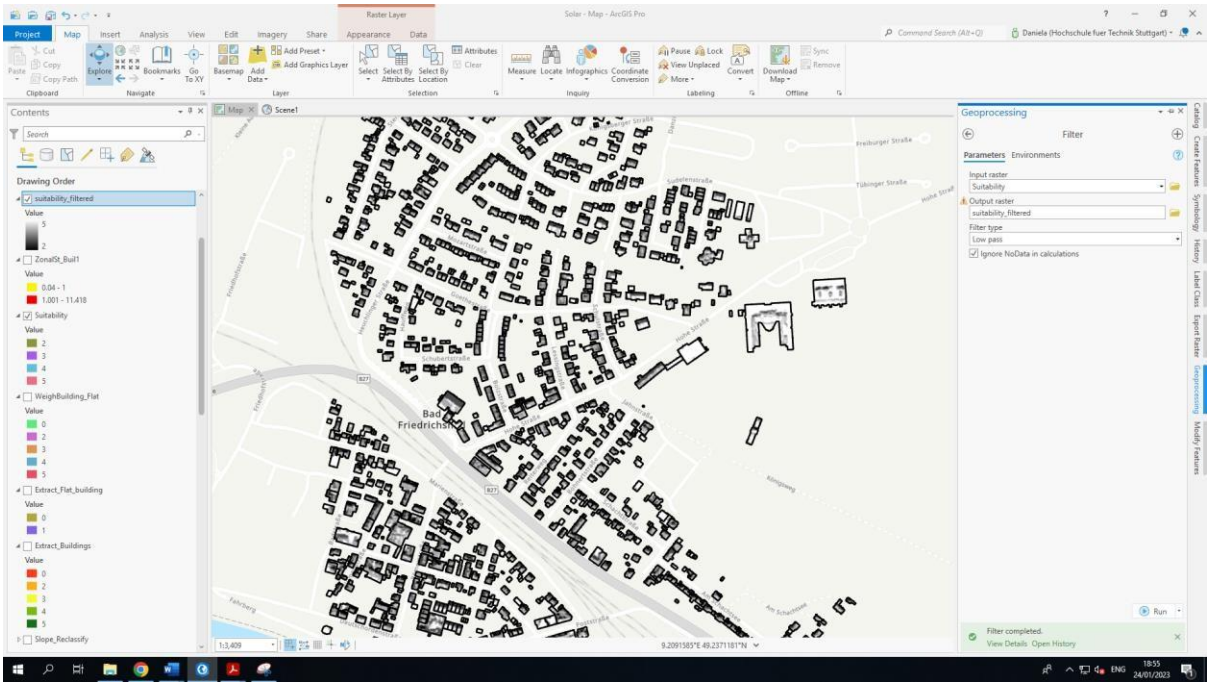

Figure 21 low pass filtered the suitability map

To have unique values in the raster, and facilitates the following analysis, the tool ‘Int’ was used.

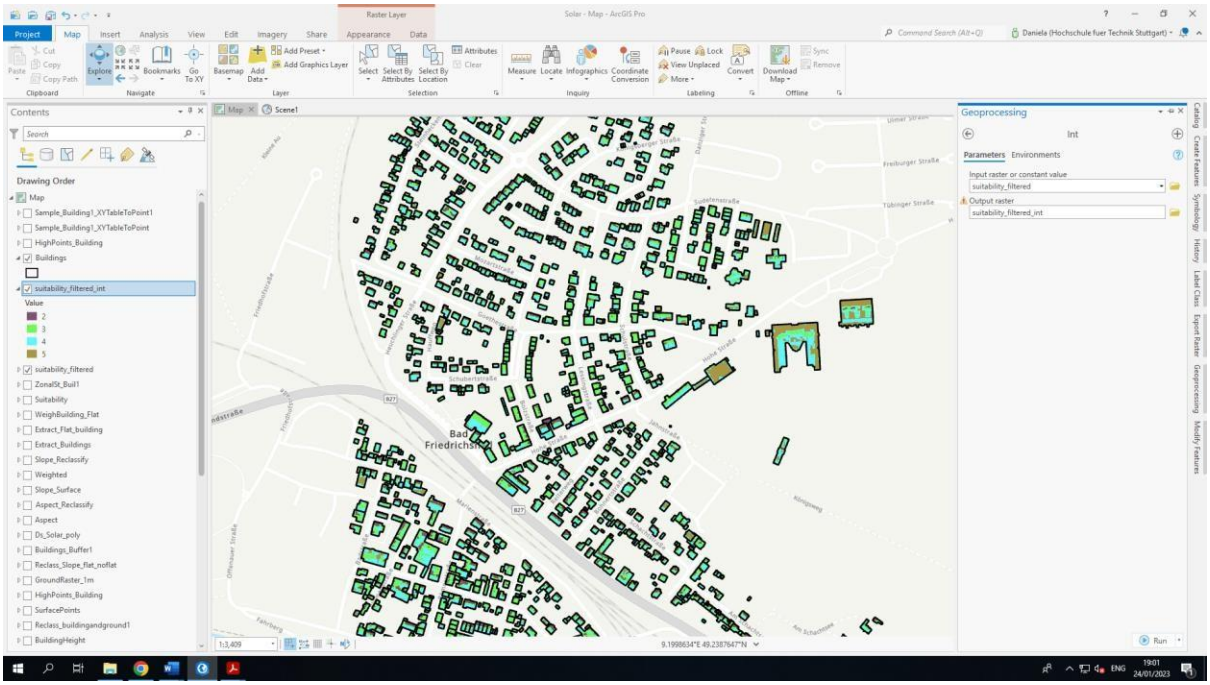

Figure 22 suitability map filtered converted into Integer

To calculate areas, combine information and perform queries the raster is converted into polygon.

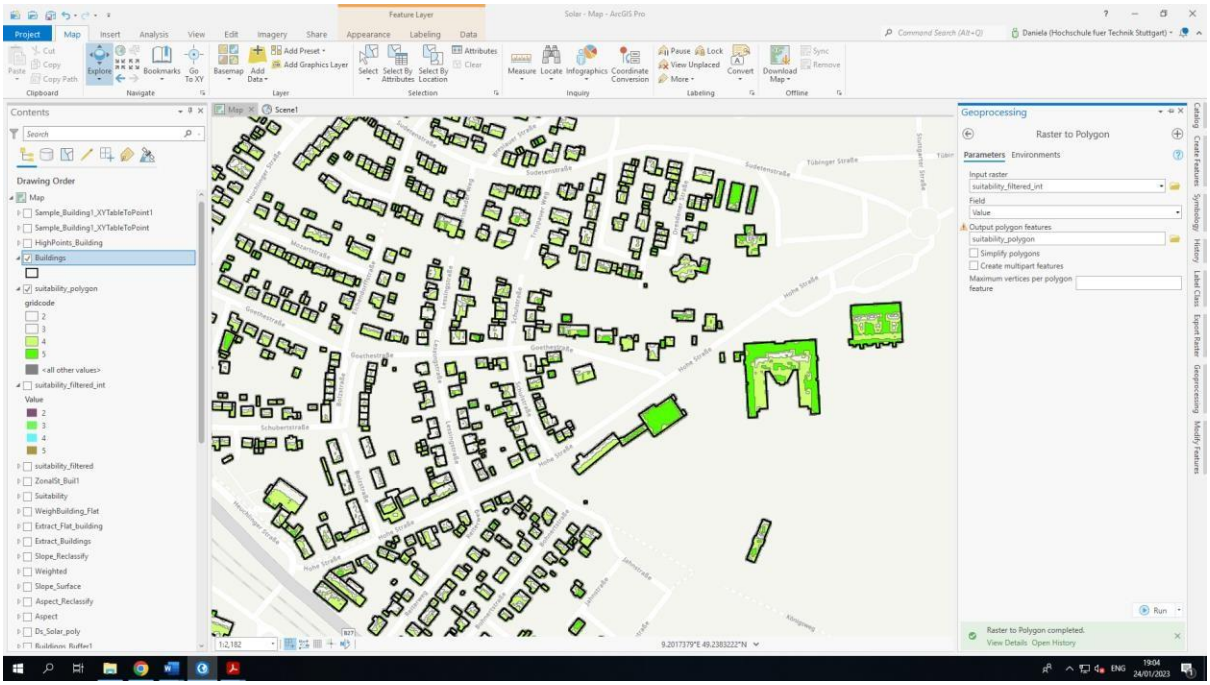

Figure 23 suitability area as polygon

To clean the areas outside the polygon's limits, an intersect is performed. This shape contains the information about the category of suitability.

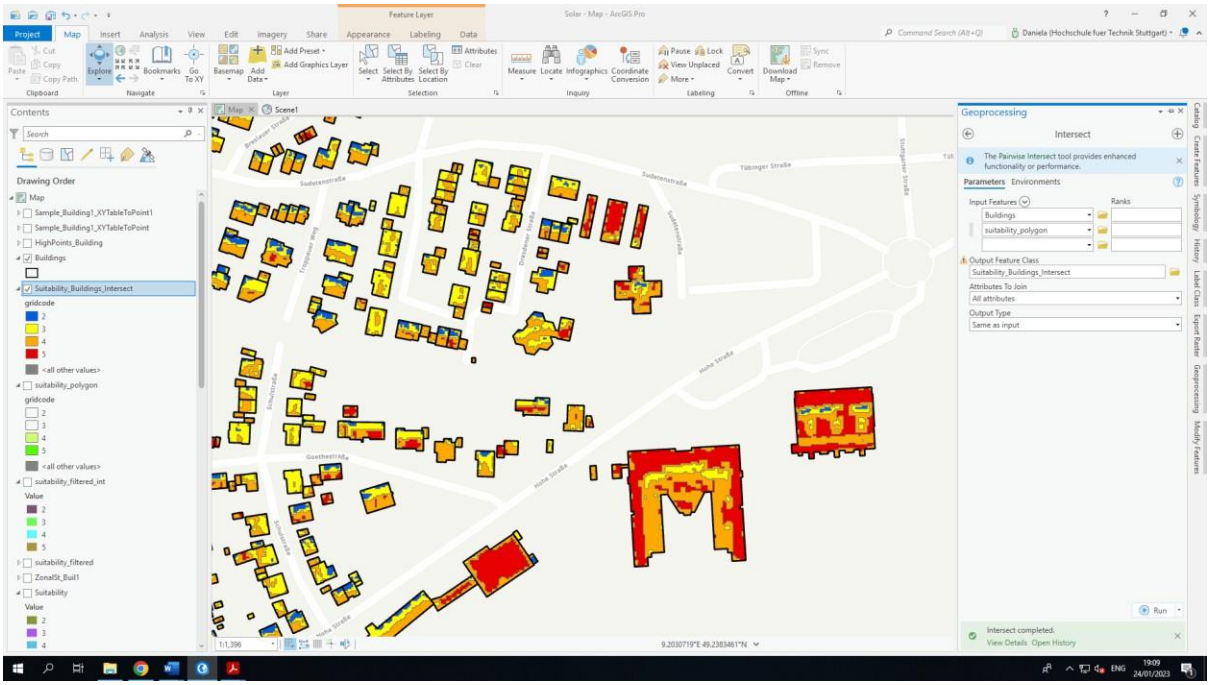

Figure 24 intersecting the suitability area with the building

2.2. Considering Standard Deviation for Detecting Flat Roof

To detect buildings that have flat roof and to have the average of building height in each building, Zonal Statistic with standard deviation method and average were performed respectively. Here, Building is used as the zone and the height points of the roof are used as raster. The output of the process is the standard deviation of height in each building.

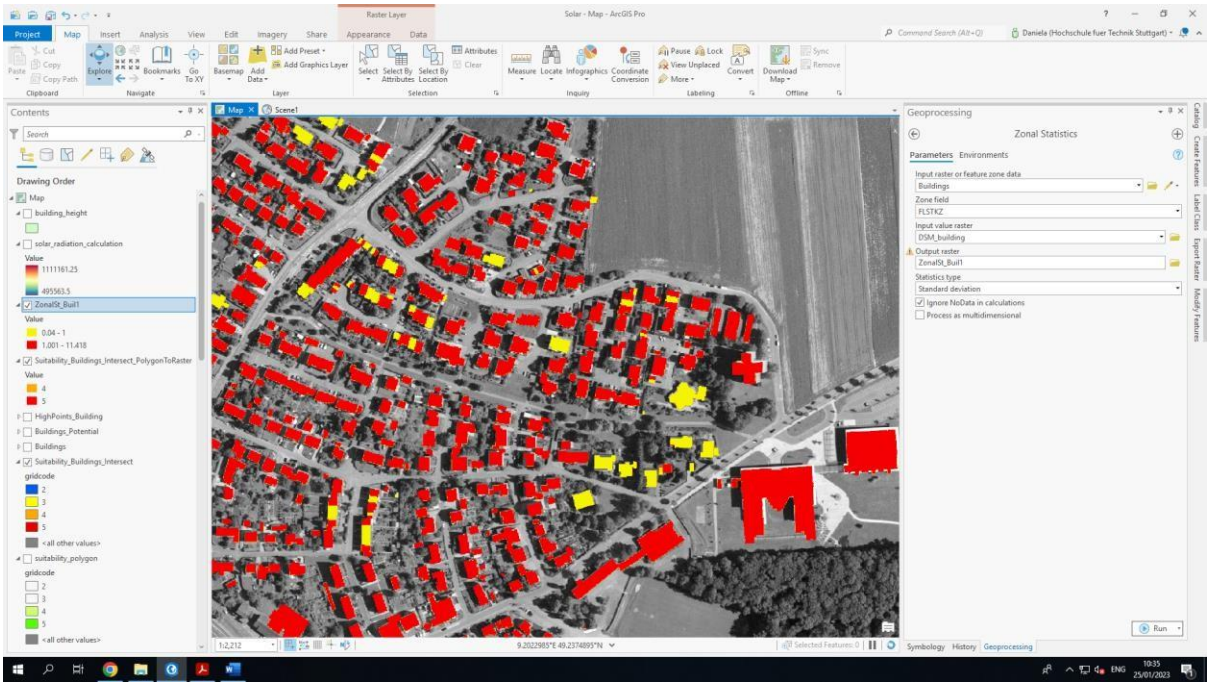

Figure roof flatness map from standard deviation of the roof height

Then reclassification is used with the assumption that the buildings that has less than 1-meter standard deviation are considered as flat. It is shown in the figure below as turquoise color.

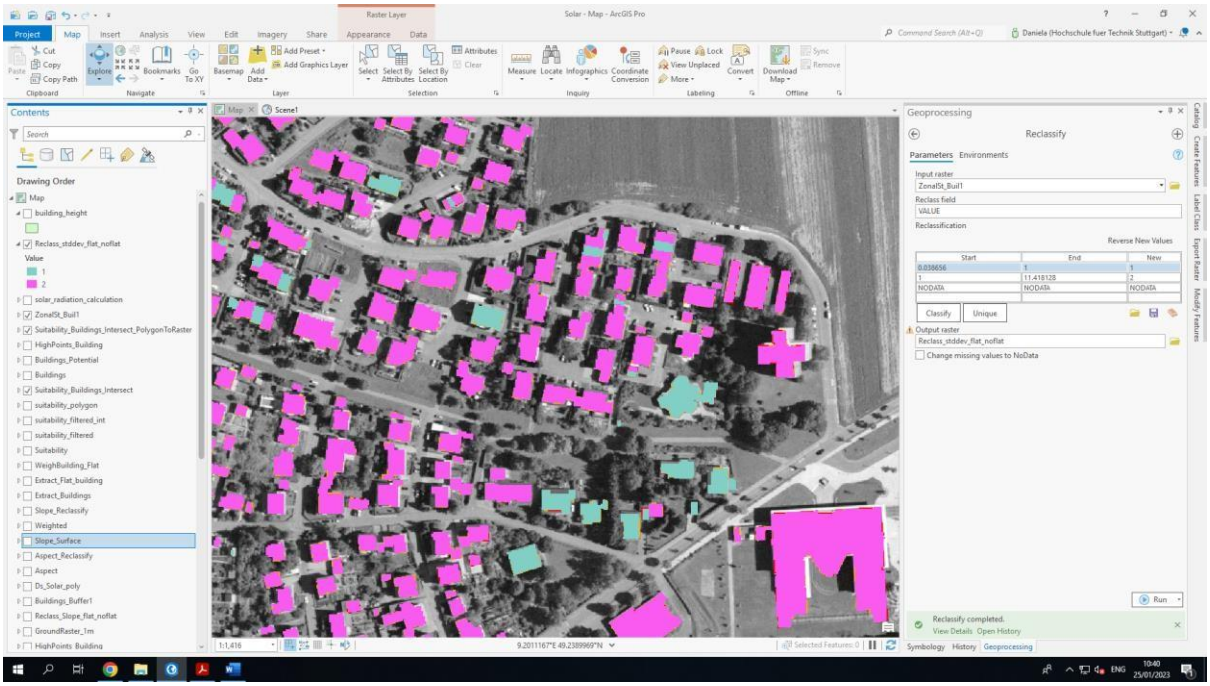

Figure 25 roof flatness reclassified

To make the process easier, the raster is converted to polygon.

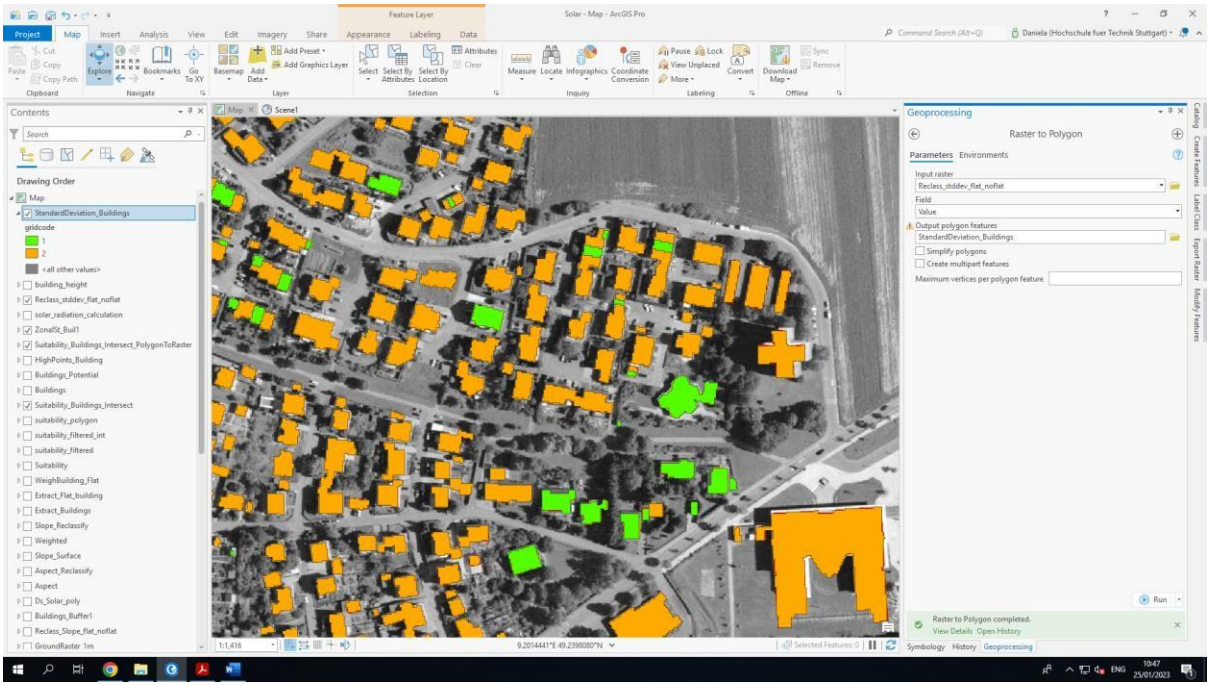

Figure 26 roof flatness as a polygon

Then the polygon was queried to have the flat category only and to select the building that has flat roof.

Figure 27 selecting the building with flat roof

2.3. Detecting Area Less Than 8-meter square

After we have the suitable area, from the weighted overlay as a polygon (Figure 24), we make a query to have the value 4 and 5 into suitable and make the rest as not suitable.

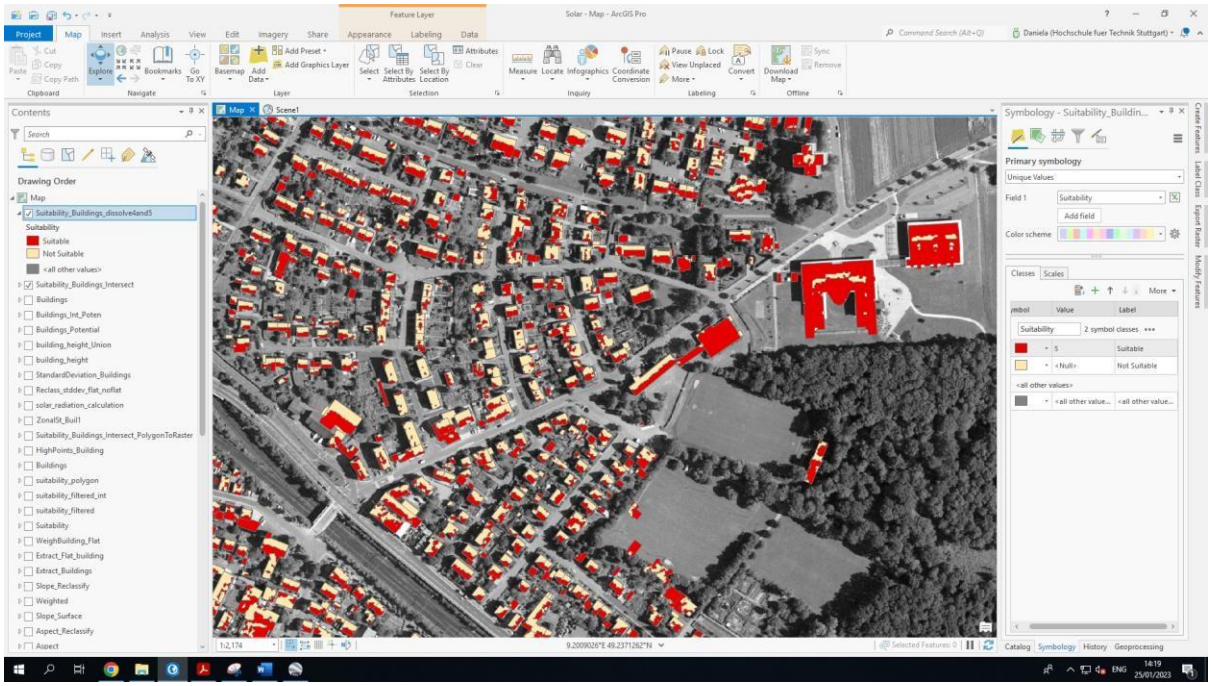

Figure 28 Determining the 4 and 5 value in weighted overlay as suitable area

Selecting the result with the building that has flat roof and making new field and put the non-suitable part into suitable. After that, the suitable parts are dissolved into one object.

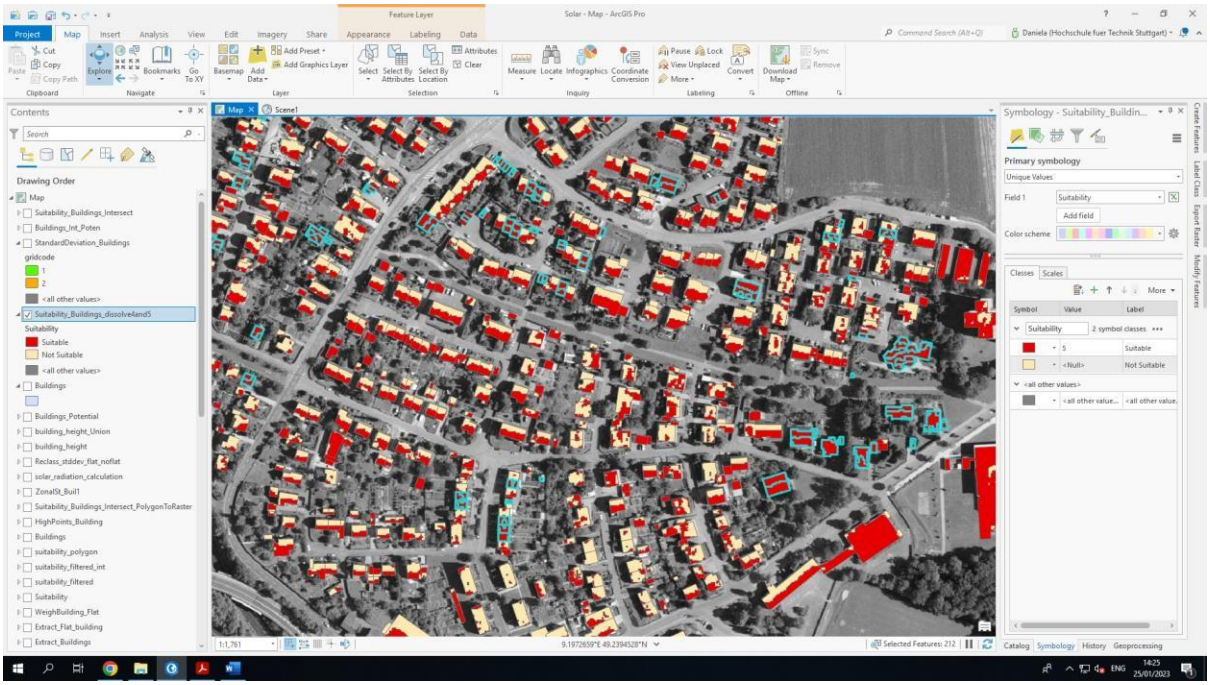

Figure 29 merging the suitable area with flat roof building

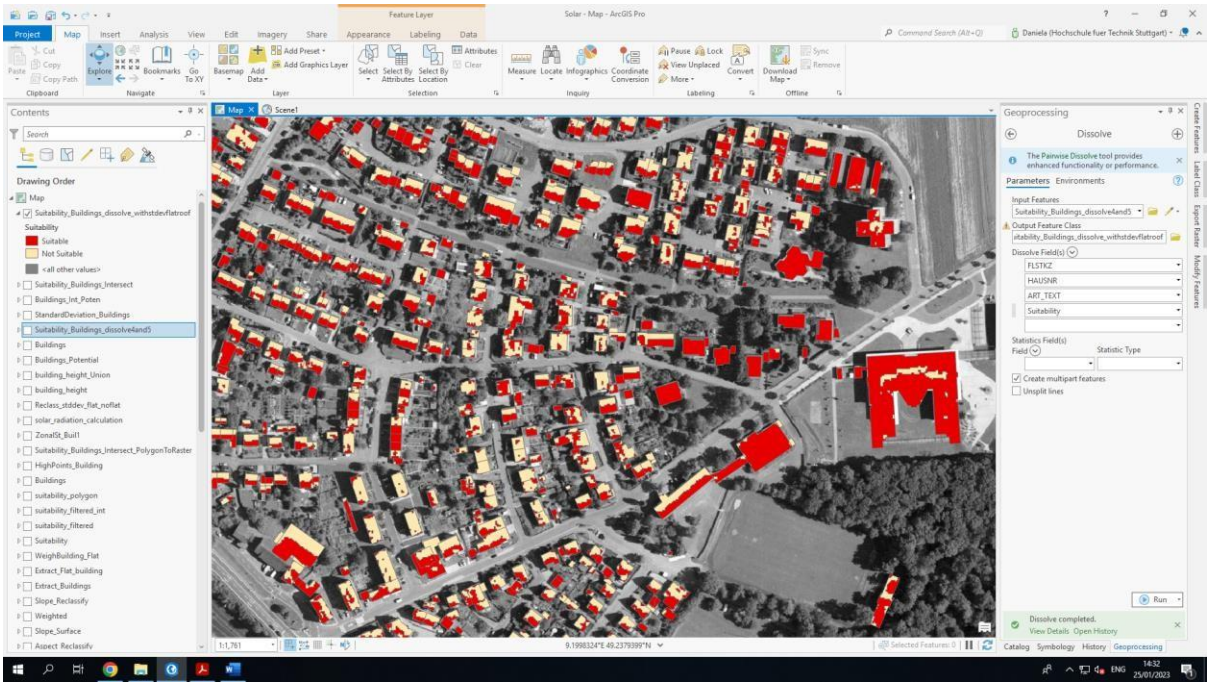

Figure 30 Dissolving the suitable area into one shape

We can see there are a lot of area which has less than 1 meter square. To solve that, the polygons are exploded and a query is performed where the area is bigger than 1 m^2.

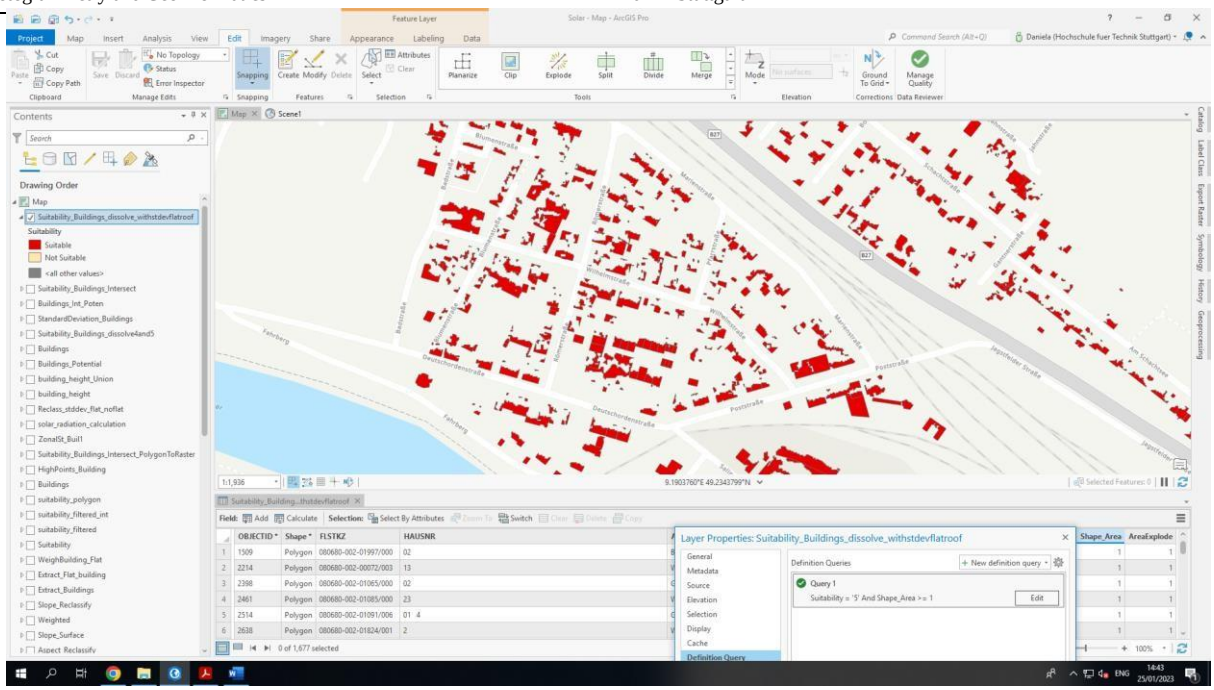

Figure 31 Suitable area with more than 1m^2 area

After the polygon which has below 1m^2 area has been removed, we dissolve the polygons which share similar building attribute. Then, we query the area which has more than or equal to 8m^2. As the result, we have the area of roof which suitable for solar panel.

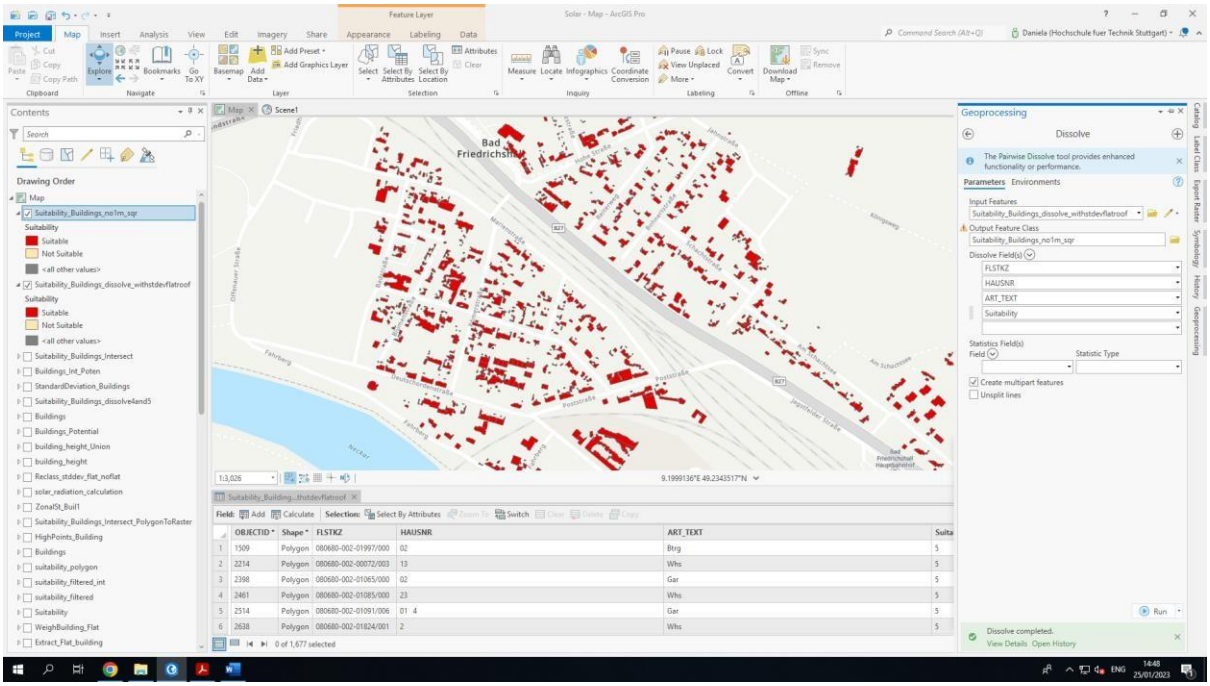

Figure 32 Dissolving the suitable area in each building

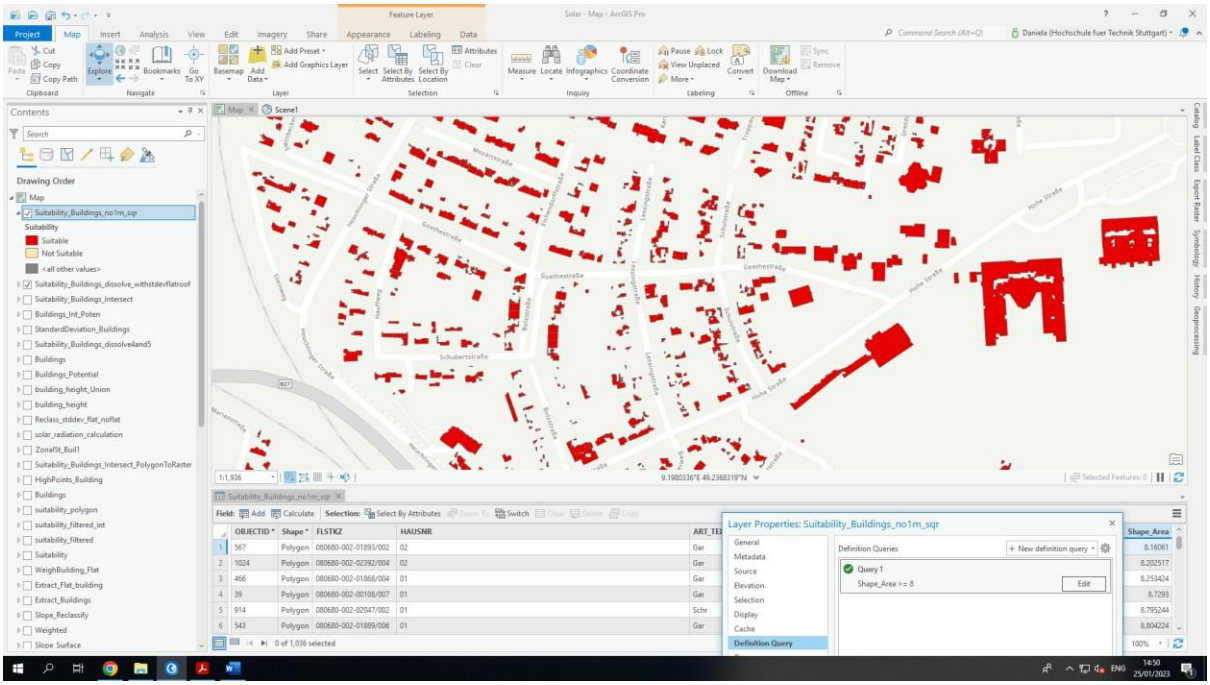

Figure 33 suitable area in each building with more than or equal to 8-meter square

3. Estimation of Energy Potential

To calculate the energy potential, we use the solar energy potential polygon given to define the area where has 1103 kWh and 1102 kWh. Then we intersect the solar energy potential polygon with the roof suitable area polygon.

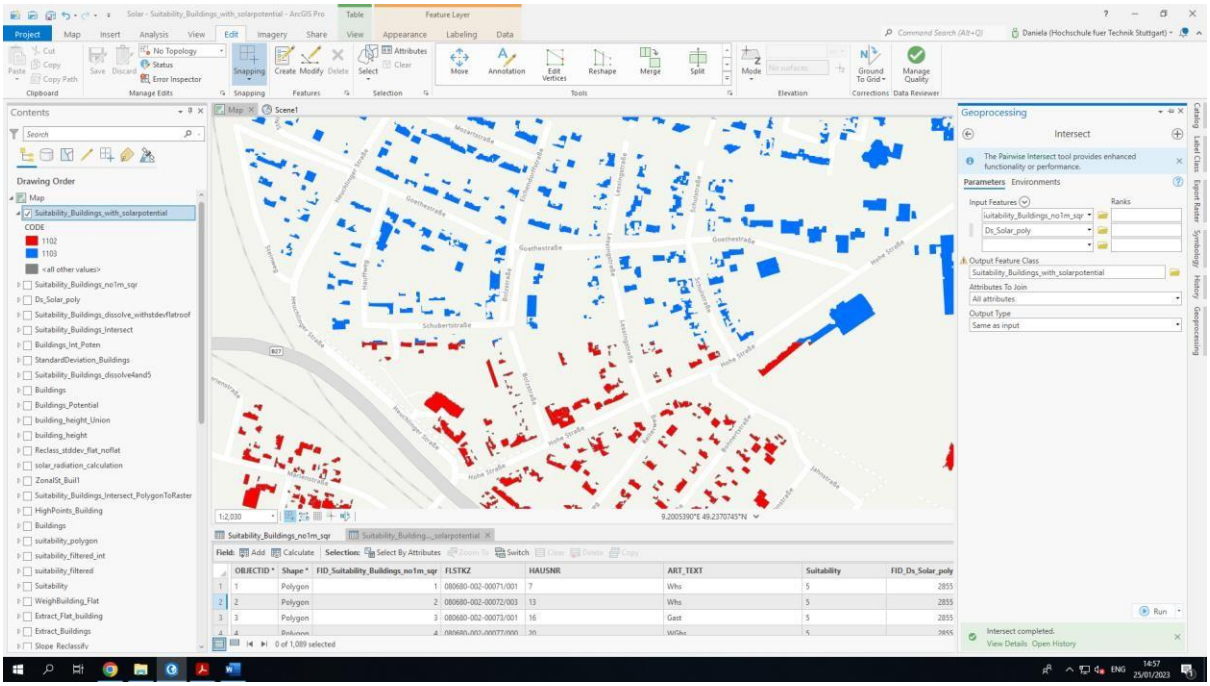

Figure 34 Solar Radiation potential in each building

To calculate the solar energy potential in each shape, new field has to be made first to do the calculation. Then, the field was calculated with formula:

$$Solar\ Potential = Area * Solar\ global\ radiation.$$

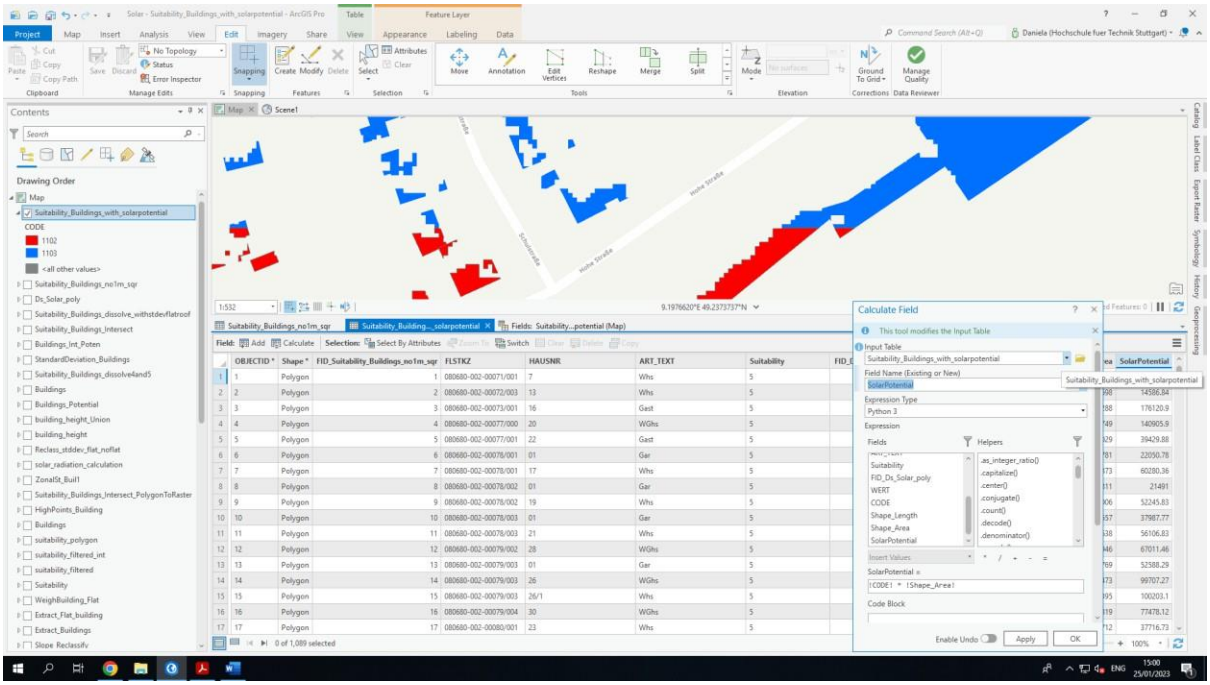

Figure 35 calculating the solar energy potential in shape

The previous process is to have the solar energy estimation for each shape, while one building can have more than one polygon. To summarize the area in each building, summary statistic is used. The result will be in a new table.

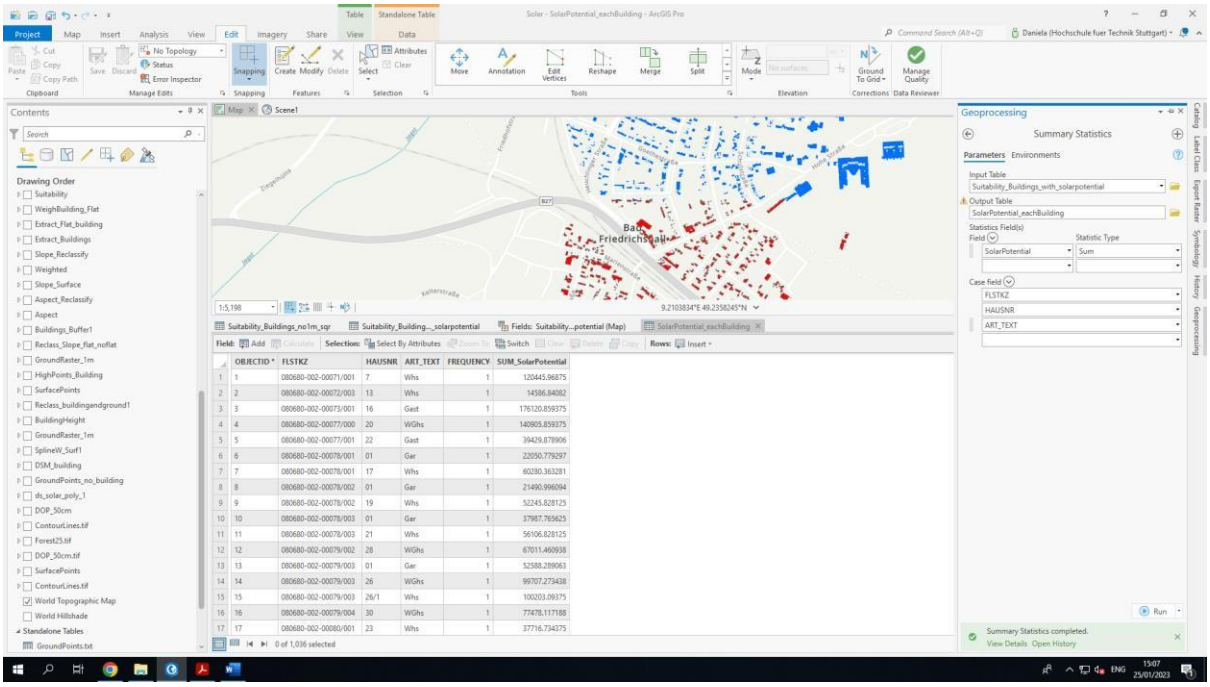

Figure 36 summarize the solar energy potential in each building

Then the table from summarize statistic is joined to the solar estimation polygon table. This process purpose is to have the estimation calculated in the polygon attribute.

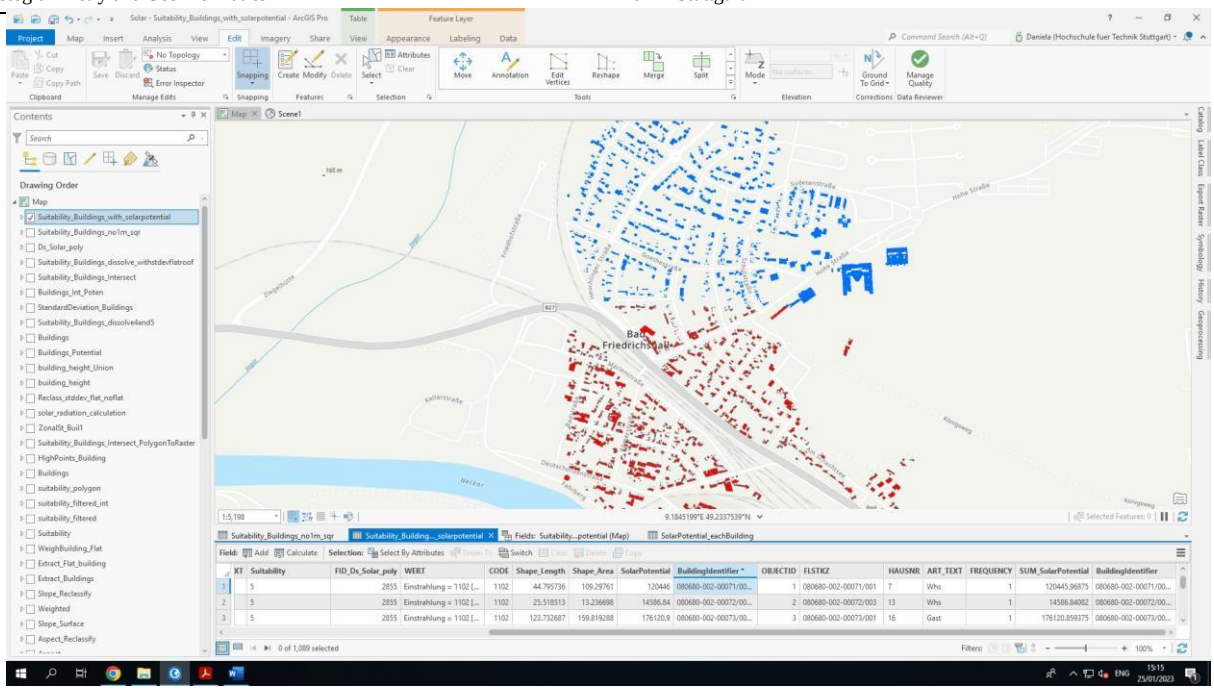

Figure 37 Joined table of the suitable area with their calculated solar energy potential

In the border area between the solar global radiation, some buildings are divided into 2 parts. To solve that, the polygon in that area should be dissolved when preserving the sum of solar and the building identity. This is the final result of the process in solar energy estimation in the study area.

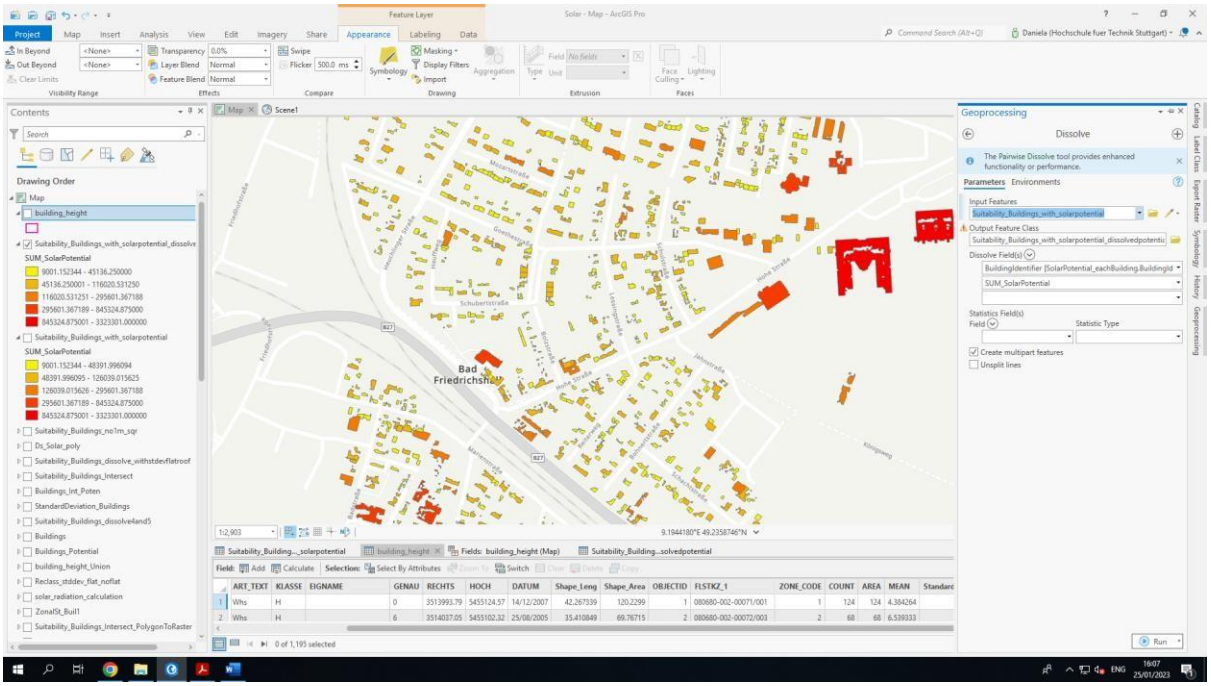

Figure 38 dissolving the polygon in building which located in the border solar radiation area

4. 3D Model of the Suitability Analysis in ArcScene

To have the 3D model, firstly, the building polygon which contain the building footprint, height of the building, and the solar energy potential estimation are needed. Building vector in the 2.2 section, has already the information regarding footprint and the height of the building. Then, the information of the summarize of the solar energy potential estimation is joined from the solar energy potential estimation process in Figure 38 using *add join.* Then, set the proper symbology.

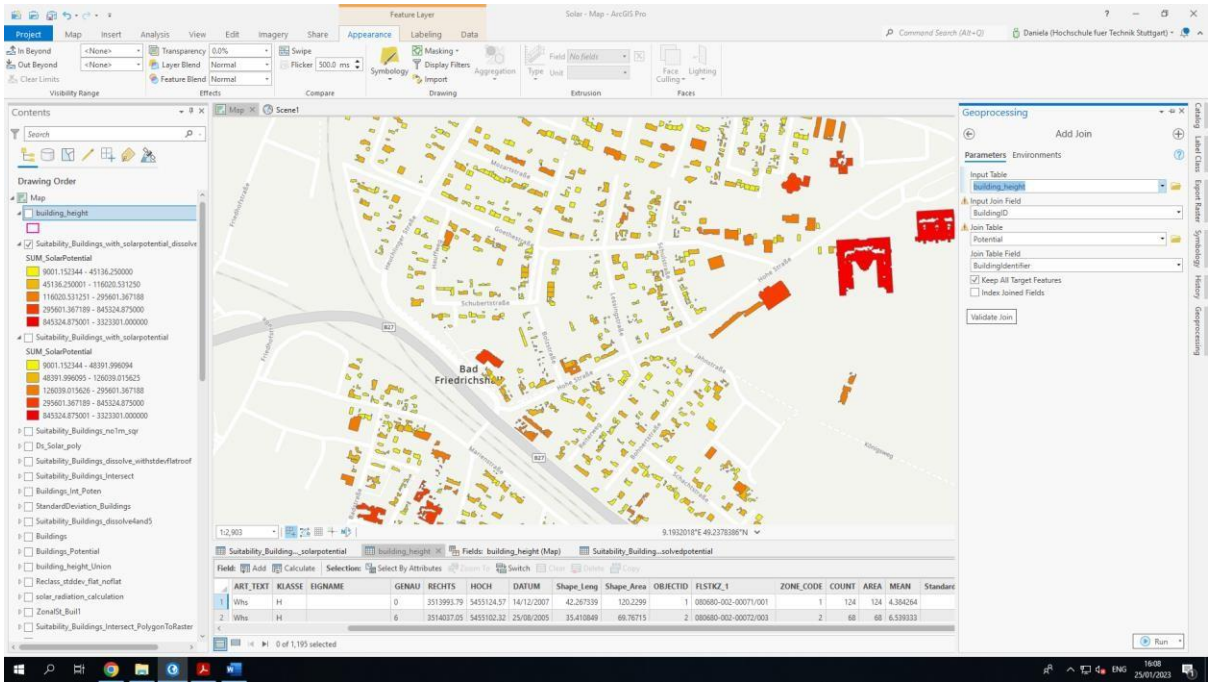

Figure 39 joining the table of solar energy potential to building shapefile

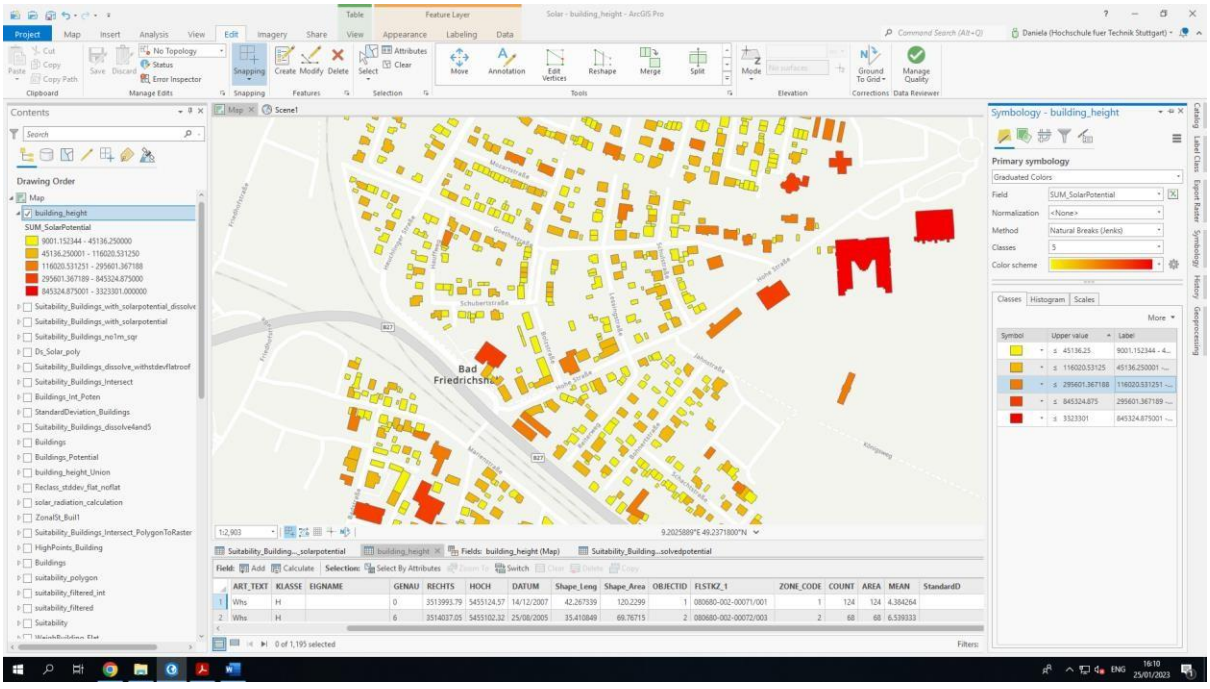

Figure 40 classified solar energy potential in each building

After we have the layer, then the layer is inserted to the *ArcScene* 3D layer, set the symbology, and the appearance. The type is set as base layer and set the column which contain height value to set the height of the building.

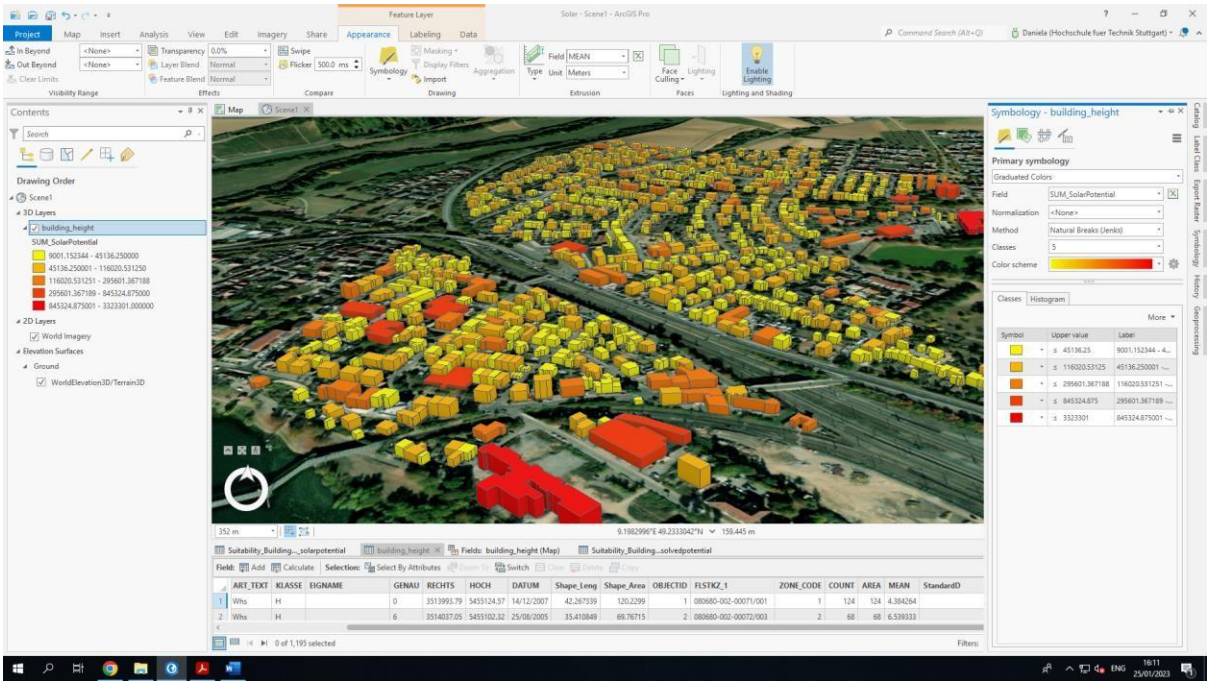

Figure 41 3D model of solar energy estimation in study area

5. Result Comparison with Landesanstalt für Umwelt Baden-Württemberg Website

As it can be compared, in general, the suitable area from Landesanstalt für Umwelt Baden-Württemberg Website and the map created in **Error! Reference source not found.**, have suitable areas that are similar. It has suitable area for the building that has flat roof and the suitable area are tend to be in the south part of the roof. One of the differences found was the new buildings, so, in many cases, the comparison could not be performed.

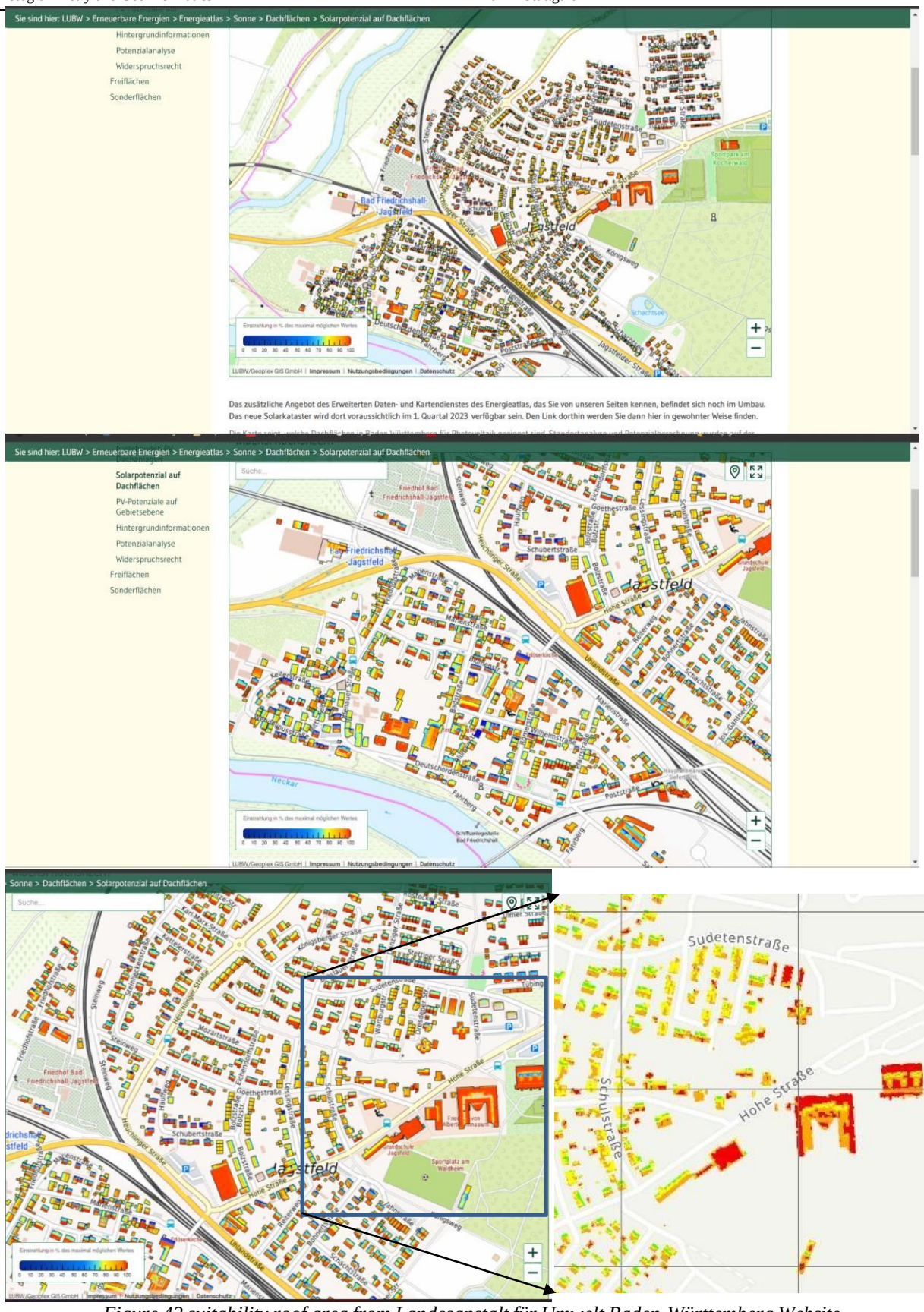

Figure 42 suitability roof area from Landesanstalt für Umwelt Baden-Württemberg Website

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Attachments:

The following maps are sent as PDF:

- Slope
- Aspect
- Solar Radiation
- Building Suitability
- Suitability categories in each building
- Suitability in 3D