

Assessment of Photovoltaic Potential in Residential Area Scharnhäuser Park

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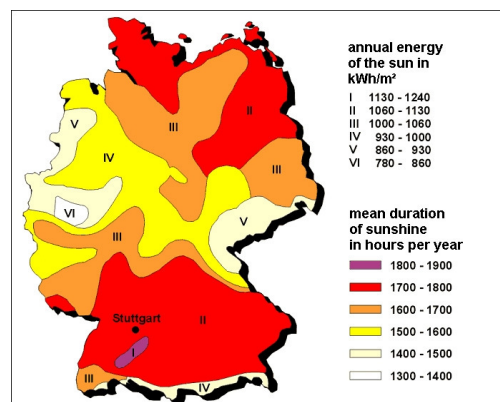
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Abstract. The solar roof potential analysis was done within a large scale urban development project called POLYCITY. This analysis focused on the residential area Scharnhäuser Park, which is located close to Stuttgart, Germany. As renewable energies are an additional source to conventional ones, they are more and more important for the production of the energy. The interesting feature is that a great deal of the necessary energy will be provided from roof top PV-systems and wood fired cogeneration plants. Laser scanner data along with GeoMedia was used for finding the potentials of roof top. The analysis was also supported with Web Application to disseminate the information to the public. The method described in this paper can serve as a good example for estimating the PV potential in other similar communities to improve the sustainable urban development.

1. Introduction

The conversion of the solar energy or biomass into heating and electrical energy is associated with the minimal environmental impact. Renewable energy systems are becoming a part of the policy, strategy and plans for regional and local development. The modern technology for the production of renewable energy can be used by communities as a contribution to the enhancement of the qualities of the given region and therefore create the image of a community as being “environmental friendly”.

One of the limitations for photovoltaic is low density of power delivered by sunlight. In Germany the annual density of solar radiation on a horizontal surface varies between 780 and 1240 kWh/m² [1], in Scharnhäuser Park the average value for the surface with 40° slope was 1299 kWh/m²a in the year of 2005.



Picture 1: Average annual duration of sunshine and global radiation in the Federal Republic of Germany, [Source: Renewable Energies in Bavaria, Bayerisches Staatsministerium für Wirtschaft und Verkehr].

According to estimations European Photovoltaics Industry Association [2] total available roof surface suitable for PV systems in Germany, France, Great Britain, Italy, Spain is 3723 km².

The solar energy is the renewable source with the highest potential. Therefore the photovoltaic can be seen as one of the most promising and environmentally-friendly sources of energy in the future. Due to the considerable potential of photovoltaic, driven from a direct conversion of solar to electric energy, it can become an alternative to fossil fuels. With the current technology and business evolution path, solar photovoltaic (PV) will have considerable impacts on bettering the environment [3].

As one of the most important applications of photovoltaic is currently electricity generation by grid-connected photovoltaic systems on roofs of individual buildings, the in this paper described research work will show the method for estimating the solar roof potential. This analysis, which will be done for the residential area Scharnhäuser Park should contribute to the sustainable development of urban areas and increase the energy efficiency. The target of this research work is to show the method of estimating the solar photovoltaic potential of the roofs in an automatic way, like by using the geo-information system. Therefore the products of the GeoMedia software family were used to execute the solar roof potential analysis on the basis of laser scanner data.

2. Case Study Area

Scharnhäuser Park (SHP) is a residential area, which is located at the southern border of Stuttgart, Germany. This area is a former military area where working places, residential areas and green park sections are integrated to result in a harmonious living and transportation environment with high comfort and low energy consumption. The area of Scharnhäuser Park has 150 hectares and 7000 inhabitants are living there.



Picture 2: Residential area Scharnhäuser Park [Source: SWE]

About 80% of the energy demand of the whole area of SHP should be supplied from renewable energies. The location of Scharnhäuser Park at the southern border of Stuttgart is advantageous regarding the use of solar energy for the electricity production from PV systems.

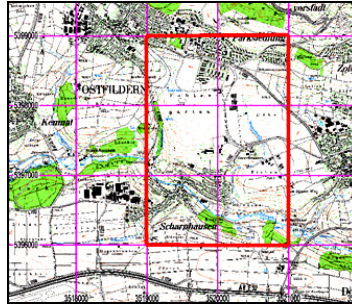
The main heating and electrical energy is delivered to the buildings of SHP from the 6,3 MWth wood fired co-generation plant. Not only co-generation plant delivers the electricity, but also the existing and planned PV-systems. Therefore, the estimation of the solar potential of the roofs for the installation of PV-systems will be needed.

3. Method

Location of SHP

The case study area of Scharnhäuser Park has a geographical dimension in Gauß-Krüger coordination systems of:

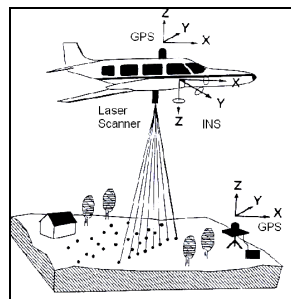
Left overhead:	Right value: 3519000	High value: 5399000
Right below:	Right value: 3521000	High value: 5396000



Picture 3: Cut-out from the topographical map (1:25000) of Scharnhäuser Park

Laser scanning

Airborne LIDAR (Light Detection and Ranging) data recording determines the digital surface models. This system measures the running time of an emitted laser beam to an object on the earth's surface and back (Picture 4).



Picture 4: Principle of airborne laser scanning [Modified from illustration in Flood, 1997]

The points on the earth are hit by the laser beam and the coordinates of these points are calculated. This technique enables to achieve a high sampling frequency and therefore a high information density. The filtering approaches enable to separate the bare ground from natural objects, which cover the topographic surface. Large objects like buildings, serve as a special challenge for filtering approaches [4].

Data available

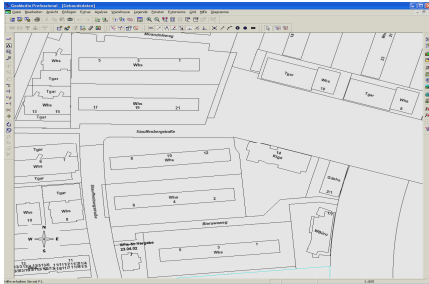
The laser scanner data for Scharnhäuser Park originate from the Land Survey Office Baden-Württemberg (LV-BW). The point density is 4 points per m^2 with a high resolution of 0,2 m. These data was captured in first and last pulse return and therefore classified into ground and vegetation points [5].

The project POLYCITY was also provided with an ALK-map of Scharnhäuser Park in DXF format, which consists of the building contours.

4. Workflow of the analysis

Initial situation

The building contours from the DXF map (Picture 5) and the high points from laser scanning serve as ground stone for the analysis of solar roof potential in Scharnhäuser Park.



Picture 5: Cut-out from the DXF map of Scharnhäuser

3519022.85	5397002.97	312.18
3519046.79	5397002.64	309.09
3519060.79	5397002.39	308.89
3519018.01	5397004.26	316.83
3519024.38	5397003.64	310.47
(...)		

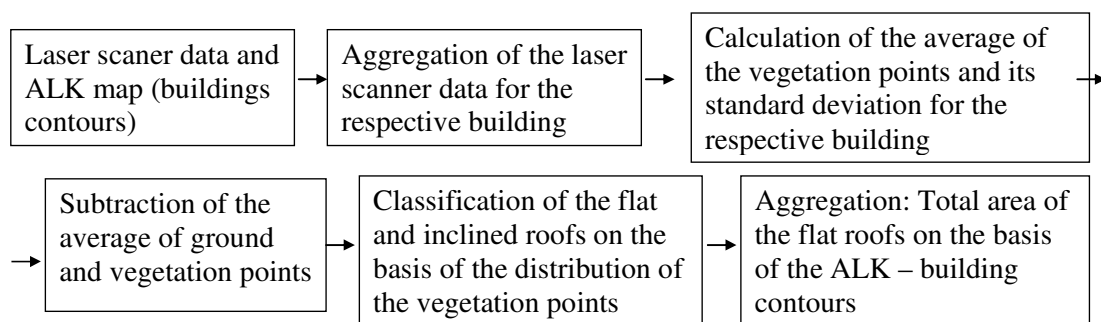
Table 1: Cut-out of ASCII-file

The coordinates of these points were delivered in an ASCII-file with laser scanner data: right value (X), high value (Y) and height (Z). The structure of this file is seen in the table above.

The target was to use the GIS (Geographic Information System) for identifying potential roof areas for the use of solar power. The GIS should detect the roofs with optimal terms for producing solar power based on laser scanner data and plan view data. Therefore, the style of roof, its inclination, orientation and size was estimated by using this system. This analysis integrates automatic sequence of algorithms and standard GIS functions, which results in the intersection of the laser scanner data and the building contours [6].

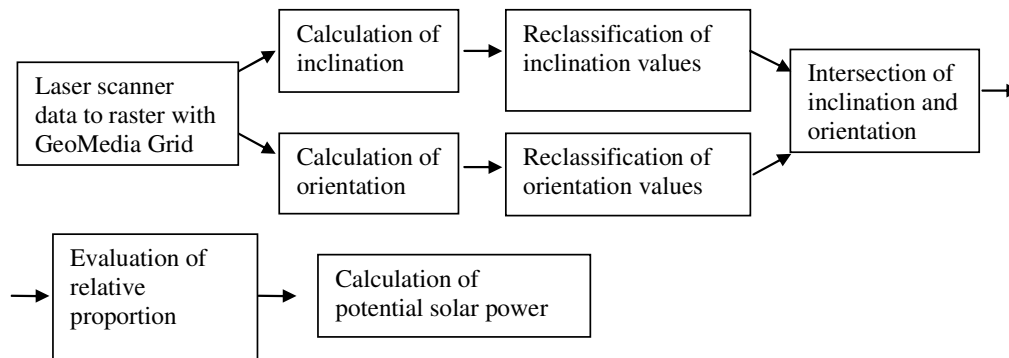
For calculation of the factors like inclination, orientation and size of the roof area the program GeoMedia Professional together with its application GeoMedia Grid was used.

In the following scheme a work flow of the solar potential analysis of flat roofs is shown:



Scheme 1: Work flow of the analysis of flat roofs

For the analysis of inclined roofs an additional application of the program GeoMedia Professional was needed, which is called GeoMedia Grid. The work flow of the solar potential analysis for the inclined roofs is shown in the following scheme:



Scheme 2: Work flow of the analysis of inclined roofs

Classification of building heights and style of roofs

The aim of this classification was to achieve a division of the building roofs of Scharnhäuser Park regarding their style, by considering the distribution of the high points. The roofs will be classified in flat and inclined roofs (Scheme 1 and Scheme 2).

The height of each point was calculated by the subtraction of laser scanner data of first pulse (building + vegetation points) and last pulse (ground points) measurement.

Additionally, a relative average height of each building was estimated, which can be later used for 3D visualization of the buildings of Scharnhäuser Park. The result of the evaluation of the building height is shown in the next picture:



Picture 6: Cut-out of the DXF-map with buildings, which are classified by average building height

This classification enabled to divide all building roofs into flat and inclined roofs. The size of the areas of flat roofs was calculated and these roofs were automatically classified as suitable for PV-installation. The inclined roofs had to be analysed in more detailed, which will be described in the next chapter.

Analysis of inclined roofs

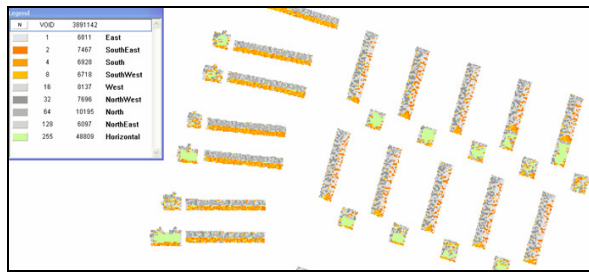
For the analysis of the inclined roofs the application GeoMedia Grid was used. Within it, it was possible to estimate the raster data from the vector data. This step delivered a data basis for the calculation of roof inclination and orientation.

Calculation of the roof orientation

The roofs should have a south orientation to make a maximal utilisation of the global radiation. A roof area, which is east or west oriented can use up to 80% of the solar energy. The orientation of the roofs was calculated within GeoMedia Grid application:

- *GeoMedia Grid > Surface > Aspect*

„Aspect“ calculates the orientation of each cell to the north direction. The results of the orientation are shown in clockwise direction: 0 for North (64 in the picture below), 90 for East (1 in the picture below) and so on.



Picture 7: Result of the calculation of the roof orientation (cut-out of GeoMedia Grid)

A raster calculator enabled to filter only south oriented roof areas, which have an orientation of 145° to 215° (2-8 in the picture above). The following formula was used for this calculation:

- *Raster Calculator* > „*aspect* >=2 AND *aspect* <=8“

Calculation of roof inclination

The optimal roof inclination is between 15°-45°. A deviation in the direction of flat roof or of inclined roof (70°) could reduce the solar gain up to 20%.

The roof inclination was calculated within the following option of the program GeoMedia Grid:

- *GeoMedia Grid* > *Surface* > *Grade*

The raster calculator enabled to filter only these roofs, which inclination was between 15°-45°.

In the last step the results of the inclination and orientation calculation were intersected. This gave as a result only for the PV-installation suitable inclined roof areas.

This process was done within the following formula of the program GeoMedia Grid:

- *Raster Calculator* > „*aspect* >=2 AND *aspect* <=8 AND *grade* >=15 AND *grade* <=45“

The result is shown in the next picture.



Picture 8: Result of the intersection of the inclined roof inclination and orientation



Picture 9: Ortho-photo image of inclined roofs

The analysis of the ortho-photo images of these buildings showed that almost all inclined roofs, which have an appropriate inclination and orientation for the PV-installation are nevertheless not suitable. The reason is that these roofs are cropped with windows, dormer windows and chimneys (Picture 9).

Despite this fact, the description of the analysis of inclined roofs was carried out in this paper to show the methodology of the estimation of the solar potential of this type of the roofs.

5. Results

Solar potential of the roofs

The analysis of the solar potential of the roofs in SHP showed that almost half of a total roof area, which was in 2005 of 98.000 m², could be seen as a suitable roof area for the PV-installation. The main reason for it is that almost 80% of the roofs of the analyzed area are of flat type. The classification of all roofs of SHP is shown in the picture below:

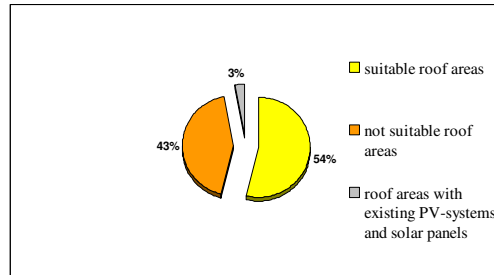


Diagram 1: Classification of the roofs

Calculation of solar energy potential

The calculation of solar energy potential of the estimated suitable roof areas considers following assumptions regarding roof orientation, its inclination, and size and also PV module efficiency:

- η : 11-12%
- H: 1299 kWh/m²a (for SHP, with 40° slope of the PV-systems)
- F: only 60% of the estimated suitable roof area
- f: 0,9 to 1,15
-

This calculation should give a general information about the potential of solar energy in SHP. Therefore a simple formula is used:

$$Y = \eta * F * H * f \quad (1)$$

Where:

- η : efficiency factor of the PV-system [-]
- F: suitable roof area [m²]
- H: average annual global radiation on the installation location [kWh/m²a]
- f: correction factor for the PV-system inclination and exposition [-]

On the basis of the result of this calculation and the average annual electricity consumption data (year 2005) it was possible to calculate the solar fraction by considering the relation between the PV energy production and the measured electricity consumption. The first general calculation showed that 40% of the electricity consumption of Scharnhauser Park could be covered by the solar energy from the PV-systems.

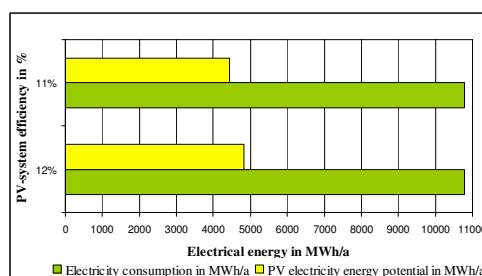
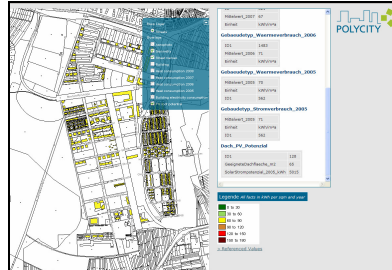


Diagram 2: PV potential and annual electricity consumption 2005 for SHP.

Additionally to make the publication of the results of the described analysis possible the program GeoMedia Web Professional was used for the development of a Web Application. Within this program a Web Map Service (WMS) was developed, which is a specification that produces maps of spatially referenced data dynamically from geographic information [7]. This WMS enabled to implement the geo-information system with the results of the described analysis into the project's website (Picture 10).



Picture 10: POLYCITY website with PV-suitable roof areas

6. Conclusions

The solar roof potential analysis described in this paper was carried out within the EU-project POLYCITY, which is a research project for sustainable development of urban areas. This analysis was done for the case study residential area of Scharnhäuser Park. The solar potential of the roofs for the PV- installation of the analyzed area was estimated by using the GIS-technology.

The PV market has a real potential for fast growth in the coming years and can therefore contribute to cover energy needs of societies. The solar roof potential analysis described in this paper can be seen as an example for estimating the solar roof potential, which can contribute to the growth of the use of the solar potential for the production of the electricity power from PV systems.

The publication of the results of this analysis should aware decision makers of potential and advantage of building integrated and applied photovoltaic and therefore supports the development of photovoltaic in residential areas. The analysis described in this paper can be repeated in other similar communities.

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