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Potential of Roof Top PV-systems for Supplying Electricity in Residential Area Scharnhauser Park

Aneta Strzalka[1], Md. Zahid Hasan Siddiquee[2], Ursula Eicker[3]

[1,3] Centre of Applied Research of Sustainable Energy Technology – zafh.net, Schellingstraße 24, D-70174 Stuttgart (Germany)
[2] GIS Specialist,EPC,Lalmatia , Dhaka, Bangladesh
E-mail of corresponding author: aneta.strzalka@hft-stuttgart.de, zh027@yahoo.com

Abstract: This study is a part of a large scale urban development project called POLYCITY dealing with how to make cities more energy efficient. The project is already in progress in three different countries like Italy, Spain and Germany. We will keep our analysis focused only on German part Scharnhauser Park, which is located in Stuttgart. In this project the working and living places are integrated in order to get a sustainable city quarter with special emphasis on minimum travel distance and low energy consumption. 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 Scanning data along with GeoMedia are used for finding the potentials of roof top. The analysis is also supported with Web Application to disseminate the information to the public. This approach will set a good example for supplying green energy in residential quarters and will provide a basis for the sustainability of similar communities.

1. Introduction

The conversion of the solar energy or biomass into heating and electrical energy produces minimal environmental impact. Renewable Energy System (RES) is becoming a part of the policy, strategy and plans for regional and local development. This technology for energy production can be used by communities as a means of enhancing the qualities of the given region and therefore create the image of the community as being "environment friendly".

The aim of this work was to produce a Geo-information system to improve the management of energy consumption by the optimisation of demand-site management, energy-savings measures and the use of renewable resources like solar energy.

The Solar Energy Planning (SEM) aims to predict the baseline energy consumption of buildings and determine the potential for reducing this by deploying the key solar energy technologies of passive solar design, solar water heating and photovoltaic (PV) systems. Results can be presented using a geographical information system (GIS). The baseline energy consumption of buildings provides the benchmark against which the effect of energy efficiency measures and solar energy usage can be compared [1].

The annual density of solar radiation on a horizontal surface in Germany varies between 780 and 1240 kWh/m², whereas average sunshine rate varies between 1300 and 2000 annual hours [2].

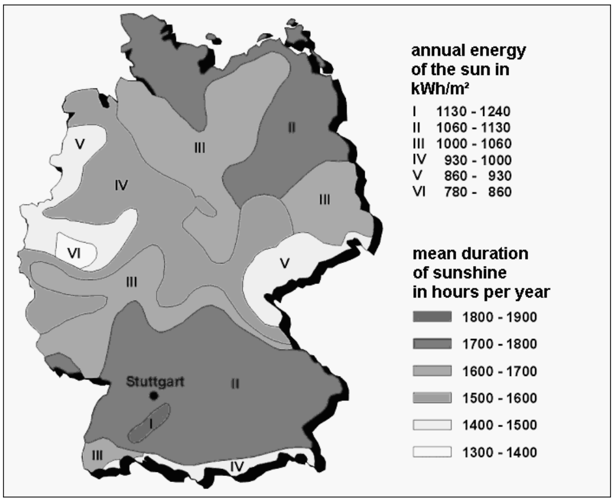

Fig. 1: Average annual duration of sunshine and global radiation in the Federal Republic of Germany, [Source: Renewable Energies in Bavaria, Bayerisches Staatsministerium für Wirtschaft und Verkehr].

The first step in the development of the solar roof potential for the installation of PV-Systems for producing the electrical energy was to collect and prepare the laser scanner data. The second step was the introduction of a GIS software tool to act as an interface to visualize and analyse these data and to allow the user display the results geographically via Web Application. The third step was to develop a methodology to estimate suitable roof areas for the PV-installation. The final one was to calculate the solar roof potential for producing the electrical energy from the PV-systems and compare it with the baseline energy consumption of all buildings of the analyzed area.

2. Project area

The project area analyzed in the POLYCITY project is called Scharnhauser Park (SHP). This is an urban conversion and development area of 150 hectares in the community of Ostfildern on the southern border of Stuttgart. Working places, residential areas and green park sections are integrated here to result in a harmonious living and transportation environment with high comfort and low energy consumption. This one is also designed as an exemplary ecological community where wood fired co-generation plants, along with roof top PV, will deliver electricity and heating energy.

Picture 1: Residential area Scharnhauser Park [Source: SWE]

3. Basics of solar potential calculation

The renewable resources considered in the described research work are solar photovoltaic (PV) power. Estimates of the solar PV resource were made for all buildings of Scharnhauser Park characterized by different type and varying in size. Here, some assumptions were made about the suitability of buildings for PV installation regarding roof orientation, roof inclination, roof size and module efficiency. Annual solar power potential for the year 2005 was calculated for the total amount of the suitable roof area.
The formula used for the calculation of solar energy potential is as follows:

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

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 [-]

The calculation considers following assumptions:

- 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

4. Assessment of data

The laser scanner data are used for the analysis of solar roof potential obtained from the Land Survey Office Baden-Württemberg (LV-BW). The point density is of 4 points per m² with a high resolution of 0.2 m. The laser scanner data were captured in first and last pulse return and therefore classified into ground and vegetation points (Fig. 2)

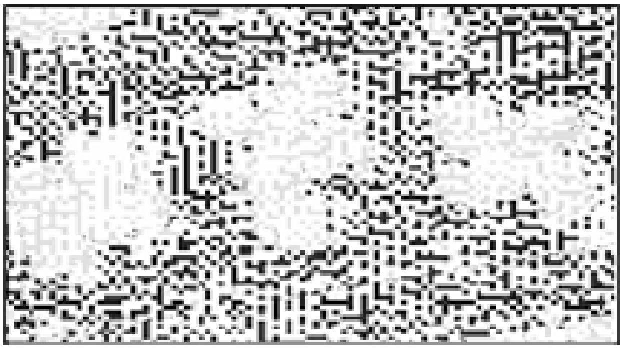

Fig. 2: Laser scanner data of first-pulse (Buildings + Vegetation) and last-pulse (Ground points) measurement

The system used measures the running time of an emitted laser beam to an object on the earth's surface and back [Fig. 3].

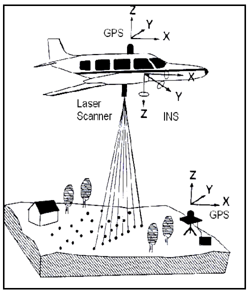

Fig. 3: Principle of airborne laser scanning [Modified from illustration in Flood, 1997]

The coordinates of the point on earth, which is hit by laser beam is calculated. The filtering approaches enable to separate the bare ground from natural objects. Large objects like buildings appear as a special challenge for filtering approaches [3].

Additional to the laser scanner data an ALK map of the analyzed area in DXF-format was used, which includes the building contours.

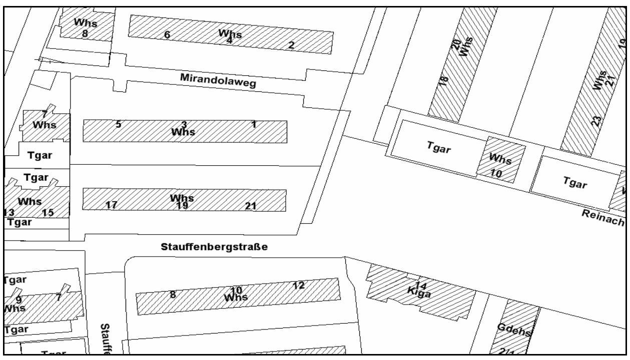

Fig. 4: Cutout of ALK map for the analyzed area SHP

5. Methodology

The program GeoMedia Professional and its application GeoMedia Grid were used as a tool to estimate suitable roof areas for the PV-installation. With the standard functions of GIS it was possible within very simple classification to estimate the buildings with height values and to separate all roofs into flat roofs and other types of roofs [4].
As most of the buildings roofs in SHP are of flat type and the inclined roofs are not suitable for PV-installation because of chimneys, windows, etc., the analysis was concentrated only on the flat roofs. The following diagram shows the whole workflow of the analysis of the flat roofs:

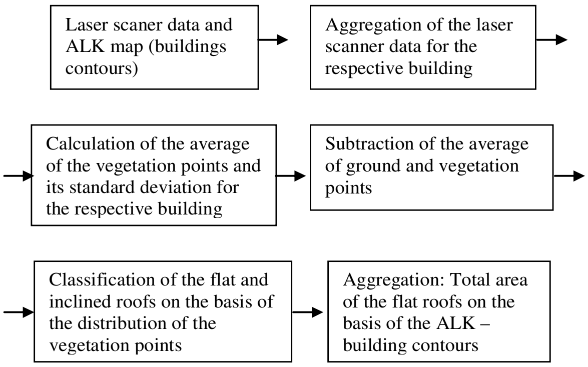

Fig. 5: Workflow of the analysis of flat roofs

6. Results

The solar roof analysis of SHP showed a great photovoltaic potential because 80% of all roofs of the study area are of flat type. Despite the fact that almost all inclined roofs are not suitable for PV-installation because of windows, chimneys, etc. almost half of the total roof area of SHP, which had a value of 98.000 m² in the year 2005, could be used for the installation of PV-systems.

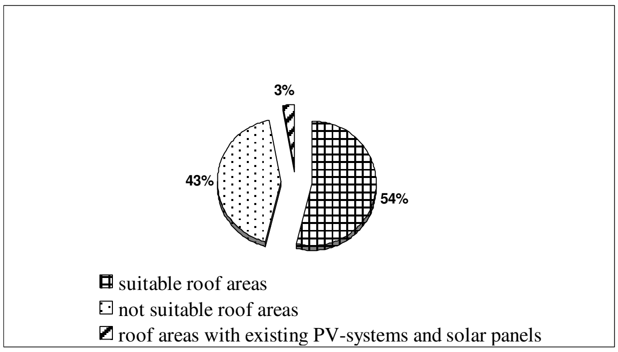

Fig. 6: Classification of the roofs

The baseline average annual electricity consumption of the buildings provided a possibility to compare it with the estimated solar potential. The first general calculation gave result that almost 40% of the total electricity consumption of SHP could be covered by the solar power from PV-systems (Fig. 7).

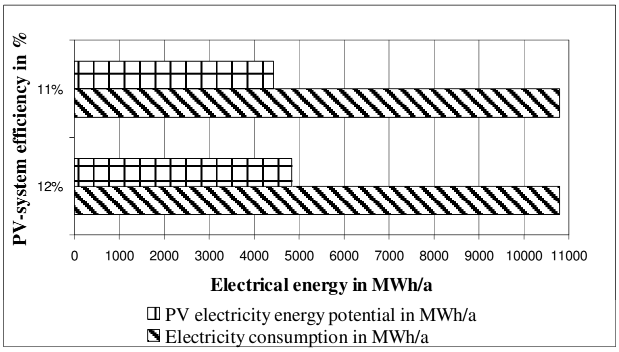

Fig. 7: PV potential of SHP for two different PV-system efficiencies and annual electricity consumption 2005.

7. Publication of the results

The results of the solar roof potential analysis were published via Web Application to disseminate the information to public. In order to publish the values of suitable roof areas with corresponding potential solar power further tool of the GeoMedia software family was used, which is called GeoMedia WebMap Professional. This tool enabled to create a Web Map Service (WMS), which is a specification that produces maps of spatially referenced data dynamically from geographic information [5]. This WMS was implemented into the POLYCITY website, which is shown below:

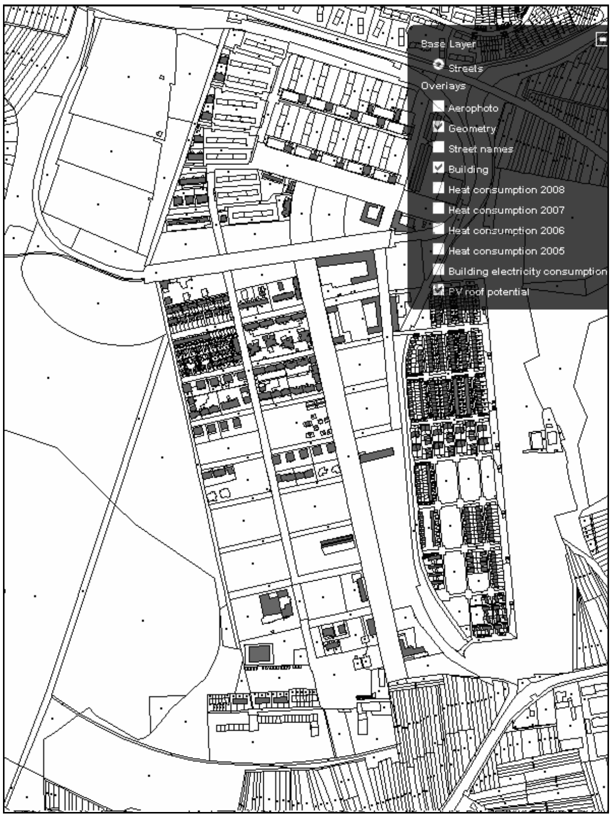

Fig. 8: POLYCITY website with PV-suitable roof areas

8. Conclusions

In this paper the solar roof potential analysis of the residential area Scharnhauser Park was investigated as a case study.

The results of this analysis gave a significant solar potential due to the fact that 80% of the roofs are flat. The potential solar power was compared with the annual total electricity consumption of SHP regarding different PV-system efficiencies. This comparison gave that almost 40% of the total electricity consumption of SHP could be covered by the electrical energy produced by PV-systems.

A web portal was designed, which provides a certain level of interactivity for the users. The method used in this research work should benefit city planners and local and regional governments in identifying cost-effective energy management measures in urban areas. It also should help utility service provider to assess the opportunities for power generation within sustainable systems.

The outcome of this paper will be integrated into the POLYCITY project to make the community of SHP as energy efficient and sustainable. Furthermore, this idea can be replicated for other similar communities having a positive impact on power saving in residential areas.

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