A GIS-based Concept for Solar Energetic Examination of New Building Projects

GIS-gestütztes Konzept zur solarenergetischen Prüfung von Neubauvorhaben

Mareike SCHOOF, Bernd RESCH, Dorothea LUDWIG

Mareike Schoof, IP SYSCON GmbH Osnabrück, Möserstraße 1, 49074 Osnabrück, mareike.schoof@ipsyscon.de

Bernd Resch, Universität Heidelberg, Berliner Straße 48, 69120 Heidelberg, bernd.resch@geog.uni-heidelberg.de

Dorothea Ludwig, IP SYSCON GmbH Osnabrück, Möserstraße 1, 49074 Osnabrück, dorothea.ludwig@ipsyscon.de

Abstract

As a consequence of a variety of geo-political and technical developments, we are currently witnessing an increasing commitment to renewable energy sources. In effect, communes react to these developments by undertaking solar energetic examinations of new building projects. However, current research solely focuses on solar potential assessment for existing structures. Furthermore, available software solutions do not consider relevant factors for decentralised energy generation right at the start of the analysis and planning procedures of new buildings and urban areas. This paper presents a concept for solar energetic examination of new building projects with special regard to communes' needs. In a first step, we examined the particular requirements in communes. Then, we created a holistic GIS-based concept for supporting the planning process of new building projects and validated it in a prototypical realisation. Our results show that GIS is likely to be a linking element between different parties involved into the planning process for new building projects (not only for existing structures) such communal planners, infrastructure operators, energy producers and political decision makers.

Zusammenfassung

Die verstärkte Nutzung erneuerbarer Energien ist vor dem Hintergrund der Energiewende ein aktuelles Thema. Die Kommunen reagieren auf diese Entwicklungen und führen zunehmend solarenergetische Prüfungen von Neubauvorhaben durch. Aktuelle Untersuchungen beschäftigen sich jedoch lediglich mit Solarpotenzialanalysen für bestehende Strukturen. Außerdem berücksichtigen vorhandene Softwarelösungen die relevanten Faktoren für eine dezentralisierte Energiebereitstellung nicht direkt zu Beginn der Planung von neuen Gebäuden und städtebaulichen Entwürfen. Dieser Artikel stellt deshalb ein Konzept zur solarenergetischen Prüfung von Neubauvorhaben unter besonderer Berücksichtigung der Bedürfnisse der Kommunen vor. Zunächst werden die Anforderungen in den Kommunen untersucht. Auf dieser Basis erfolgen die Erstellung eines GIS-gestützten Konzepts zur Unterstützung des Planungsprozesses sowie eine Validierung anhand einer prototypischen Umsetzung. Die Ergebnisse zeigen, dass GIS als Bindeglied zwischen verschiedenen am Planungsprozess beteiligten Akteuren, wie Kommunalplanern, Infrastrukturbetreibern, Energieerzeugern und politischen Entscheidungsträgern, dienen kann (nicht nur für bestehende Strukturen).

Keywords:
Solar energetic examination, planning, renewable energies, GIS
Solarenergetische Prüfung, Solare Bauleitplanung, Erneuerbare Energien, GIS

1 Introduction

As a consequence of a variety of geo-political and technical developments, we are currently witnessing an increasing commitment to renewable energy sources. Particularly in Germany, the percentage of renewable energy has increased significantly over the last years, mostly due to the Renewable Energy Law (Erneuerbare-Energien-Gesetz – EEG) (BMWi; BMU 2012).

This focus has two far-reaching consequences: First, from a consumer viewpoint, lower consumption of energy and thus a reduction of energy-related expenses play an important role. Second, at the same time, many people are becoming more environmentally conscious and want to live in a more sustainable way (Umweltbundesamt 2008). They are well aware that they can actively contribute to a transition in energy production and usage from fossil fuels and nuclear energy to renewable sources by using solar energy.

In effect, communes are currently starting to react to these developments by undertaking solar energetic examinations of new building projects (Stadt Augsburg 2007, EnergieAgentur.NRW 2011). Most current approaches solely focus on using existing infrastructure for decentralised energy generation, for instance, by actively harvesting energy from solar panels mounted on commercial and residential buildings' roofs. Thus, new building projects are neglected in most cases in solar potential analysis.

However, relevant factors for decentralised energy generation and savings need to be considered right at the start of the analysis and planning of new buildings and urban areas. The aims of solar energetic urban planning are 1.) increasing use of renewable energies and 2.) passive as well as active energy savings. Relevant factors are building's compactness and orientation, the slope of the roof surface, shading, improved heat protection, and efficient energy supply. Optimising these parameters can lead to lower heating requirements (Goretzki 1998).

By considering the above mentioned factors, energy-efficient architecture can be integrated into an urban development process. Yet, existing analysis software is mostly inadequate and not sufficiently developed. This means that suitable software tools, which enable an automatic analysis and planning, are missing.

This paper presents a concept for solar energetic examination of new building projects with special regard to communes' needs. Our work contrasts or extends previous work in two ways: first, by considering new building projects instead of existing built structures; and second, by focusing on urban planning processes rather than on individual buildings.

The methodology of the research presented within this paper is as follows. In a first step, we examined the particular requirements in communes and their actual need for solar potential planning tools. For this purpose, we developed a questionnaire, which focuses on assessing the requirements for the use of Geographic Information Systems (GIS) based software for planning new buildings and urban areas under thorough consideration of solar energetic aspects.

On the basis of the survey results, we developed a GIS-based software concept to support the growing need for leveraging renewable energies, which in turn requires consideration of numerous small, regionally spread energy sources. Our results show that GIS can potentially be a linking element between different participants like communal planners, infrastructure operators, energy producers and political decision makers.

This paper is structured as follows: This introduction is followed by a section on related work. Thereafter, we elaborate on our methodology and requirements analysis in section 3. The concept is presented in section 4 and is followed by the results of the practical realisation in section 5. Finally we give a conclusion.

2 Related Work

We are currently witnessing an increasing commitment to renewable energy sources. The acquisition and provision of energy information are important aspects in the process of energy transition, which communes are bound to by the Geodata Access Act (Geodatenzugangsgesetz) (KOMMUNALES KOORDINIERUNGSGREMIUM GDI-DE 2013).

Up to now, communes often use solar potential cadastres for existing buildings (BRÜCKNER & LAKES 2012). However, climate protection is also increasingly integrated in urban planning. Various communes have already made approaches for energy savings and CO_2 reductions by using solar energy. Examples include STADT AUGSBURG 2007 and ENERGIEAGENTUR.NRW 2011. In the 1990s, GORETZKI 1998 already developed paper-based templates as well as a software programme as tools to support solar energetic urban planning.

Regarding the energy transition to renewable energy sources it is important to develop new supply concepts. Decentralised as well as centralised approaches like smart grids and super grids are possible, which can also be combined with each other (KROPP 2010).

SÚRI & HOFIERKA 2004 developed a process that generally deals with solar radiation analysis using the *GRASS GIS* function r.sun. Furthermore, there are different methods for calculating the incident radiation for building facades from CARNEIRO ET AL. 2009, JOCHEM ET AL. 2011, HÖFLE 2012 or HÖFLE & JOCHEM 2012 on the basis of laser scanning data.

The current approaches focus on existing building structures on the basis of laser scanning data. In contrast, this paper deals with new building projects. The building facades' position and aspect are known as the buildings are planned and modelled by ourselves. Thus, laser scanning data is not required. Nevertheless, point based methods are also conceivable for solar radiation analysis. This work analyses and shows the possibilities of a GIS-based realisation. This is especially important as it deals with a spatial question and the methods for solar radiation analysis are based on GIS functions.

3 Requirements Analysis for Solar Energetic Examinations of New Building Projects

For assessing communes' needs in terms of solar energetic planning of new buildings and urban areas, we designed a questionnaire containing ten questions. On the one hand side, they deal with tools and programmes that are already used for solar energetic examinations, their possible deficits and their frequency of use. On the other hand side, the requirements for future software, the use of GIS as well as legal frames and regulations that have to be observed, are queried.

The questionnaire has been realised using the online service *SoSci Survey* (SoSci Survey 2012). The evaluation has been performed by using the statistical software SPSS (IBM SPSS Statistics 2012). Altogether, about 300 communes were surveyed, of which on average of 73 answered the questions.

This section presents the results of the user study. The result discussion and interpretation for each question are done in sub-section 3.1 separately for every question, whereas an overall discussion and conclusion for the survey are presented in sub-section 3.2.

3.1 User Study

Question 1 asked whether a commune already performs solar energetic examinations for new building projects (yes/no). Only 18.4% (18 out of 98) of the surveyed communes answered this question with "yes". This low number is quite surprising – even though the authors expected a rather low percentage – as a higher number would have been perfectly plausible considering the ongoing public debate subsumed under the term "energy transformation". Yet, this low percentage clearly underpins the need of the performed survey and the research presented within this paper.

Question 2 asked, which tools and programmes communes are currently using for solar energetic examination of new building projects. Participants could specify up to five tools and programmes in free-text answers. Some communes are using a specialised software tool and some even still execute a manual analysis of the planning using paper-based templates. This again shows the necessity for fostering communes' awareness for the opportunities of using GIS-based analysis software in planning new building projects.

Question 3 asked about the usability of currently used tools and programmes. Answering possibilities were pre-defined: "very good", "good", "acceptable", "rather bad", "bad". The usability of the specialised software programme GOSOL is only rated as "acceptable" because the programme's handling, data output and transfer are difficult. A major disadvantage is that it works at DOS level, so that the compatibility with other programmes and data formats cannot be guaranteed. On the other hand, the manual analysis is rated as "good".

Question 4 asked to specify deficits of these currently used tools and programmes. To make the question easily understandable to all test persons, who potentially have heterogeneous educational backgrounds and knowledge bases, a few possible criteria such as map portrayal, functionality, integration with other systems, supported data formats, etc. were given. The specialised software programme is criticised mainly because of its data output, the integration with other systems as well as the layout of resulting maps. The manual analysis is rated as not accurate enough.

Question 5 asked how often the available tools and programmes are used. Four out of six communes undertake solar examinations at every planning or often, two only at times.

Question 6 asked whether communes consider software for supporting planning processes in solar energetic examinations of new building projects useful. The question was asked in a yes-no fashion with an additional possibility of giving free-text comments. 58.9% (43 out of 73) of the communes regard such software as practical and helpful. The free-text answers show that the focus should not be set on individual construction projects, but on urban planning. A newly developed software tool should provide functions for calculating the passive solar potential, the reasons for reduced solar gains (e.g. unfavourable orientation or shading) and the examination of incident radiation according to DIN 5034 (German norm for daylight in interiors) and possibly determination of the active solar potential.

Question 7 asked whether communes are already using Geographic Information Systems (GIS). Additionally to a yes-no choice, participants were asked to name the GIS tools they are currently using. Regarding the GIS-based concept, which is to be developed, it is remarkable that 97.3% (72 out of 74) of the communes already have experience in using Geographic Information Systems. *ArcGIS* is the most frequently used GIS software tool.

Question 8 asked, which legal regulations communes need to comply with when performing solar energetic examinations. The free-text answers concerning these laws and regulations comprise the German Building Code (Baugesetzbuch – BauGB) and the corresponding building codes of the individual federal states, the Renewable Energy Heat Act (Erneuerbare-Energien-Wärmegesetz – EEWärmeG) as well as the Energy Saving Ordinance (Energieeinsparverordnung – EnEV). In addition, some communes have established their own directives, design statutes or determinations in land use plans.

Question 9 dealt with the communes' notion of the importance of considering solar energetic parameters already in the planning phase of new building projects. Answering possibilities in this closed question were "very important", "important", "medium", "less important", and "not important". As shown in Figure 1, a percentage of 74.3% (55 out of 74) regard the consideration of solar energetic parameters as "very important" or "important". This indicates that the communes realise the importance of solar energetic examinations.

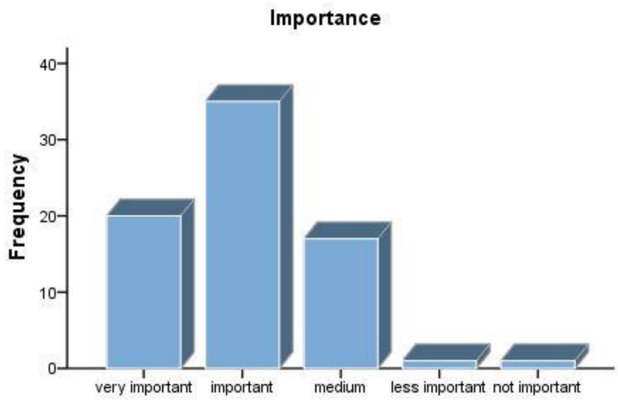

Fig. 1: Number of communes that regard the consideration of solar energetic parameters as “very important”, “important”, “medium”, “less important” and “not important”.

Question 10 finally asked whether communes would perform solar energetic examinations themselves or whether they would hand this task over to an external service provider. 70 communes answered this question: 25.7% indicated that they would perform the examinations themselves, whereas 45.7% would contract an external company with this task. 12.9% indicated that they would do both. This in turn means that there is a significant demand for service provision in the area of solar energetic examinations for new building projects.

3.2 Conclusions from the User Study

The user study shows that only few communes perform solar energetic examinations of new building projects until now, but the interest and the need are widely present. This becomes apparent as the majority of communes would appreciate software for solar energetic examination of new building projects and almost 75% regard the consideration of solar energetic parameters at the planning as “very important” or “important”.

Therefore, the aim of the concept, which is to be developed, is to increase the percentage of communes performing solar energetic examinations of new building projects by providing a usable and comprehensive software tool. Here, the use of GIS plays an important role as almost all communes have experience with it. That is why a future tool for solar energetic examination on the basis of GIS is desirable and reasonable. Furthermore, it has to be simple, understandable and easy to handle.

An evaluation of different software, for example PHPP, TAS Building Designer, PV*SOL, has shown that most programmes regard just one aspect of solar energetic examination or do not consider interactions between the factors. A user friendly tool may stimulate the communes’ readiness to perform solar energetic examinations and thus increase their percentage.

4 GIS-based Concept for Solar Energetic Examination

The survey presented in section 3 constitutes the basis for the development of a GIS-based concept for solar energetic examination of new building projects. It shows that there is a need for action as most communes do not consider solar energetic parameters in their planning projects although they regard them as important. The general aim of the concept is that a wide range of communes will perform solar energetic examination of new building plans in the near future. Therefore, it is necessary to develop a concept that includes all relevant solar energetic factors. In the next step, workflows have to be optimised. This can lead to an improvement in efficiency of solar energetic examinations of new building projects. In the future, solar energetic factors should not only be considered in the planning of special solar settlements with passive houses or so-called “three-liter houses”, but become a standard procedure in every planning process. The following paragraphs list the main factors that we have identified to be essential in solar energetic urban planning, including their limiting aspects.

Generally, the loss of incident radiation due to unfavourable *orientation, shading and topography* should be reduced to 20%. Therefore, at first the deviation of the main building facade from south direction should not exceed 45°. Furthermore, the shape of the building’s construction should be compact with minimal dissection or offset. The compactness is expressed by the A/V ratio, which is defined as the ratio of area (A) over volume (V) and should not exceed 0.65 m^{-1} on average (ENERGIEAGENTUR.NRW 2011).

Energetically favourable *roof* types are flat, saddle, pent or barrel roof. The ideal roof pitch for an active use of solar power by photovoltaic systems lies between 25° and 45°. In order to reduce shading to a minimum, the distance between neighbouring buildings and trees has to be large enough. This distance is dependent on the heights of the buildings and the trees. The characteristic value that expresses this issue is the so called A/H ratio (distance (A) over height (H)). For buildings it should not be smaller than 2.7 and for trees it lies between 1.5 and 2.7 depending on the tree species and the tree’s position (GORETZKI 1998).

The *solar radiation analysis* plays an important role in solar energetic examination. It requires a Digital Elevation Model (DEM) of the examination area with all buildings and vegetation objects. The main challenge is to calculate the incident radiation for the building facades. There are different approaches from CARNEIRO ET AL. 2009, JOCHEM ET AL. 2011, HÖFLE 2012 or HÖFLE & JOCHEM 2012 to solve this problem.

In this context, the *incident radiation* according to DIN 5034 has to be examined in order to guarantee sufficient brightness for living rooms. The possible period of incident radiation should amount not less than 1 hour for at least one living room on 17 January (NORM DIN 5034).

In compliance with ENEV 2009, heating requirements have to be calculated according to different DIN standards which are in particular DIN V 18599 (Energy efficiency in buildings), DIN EN 832 (Thermal performance of buildings), DIN V 4108 (Thermal insulation and energy economy in buildings) and DIN V 4701 (Energy efficiency of heating and ventilation systems in buildings).

Summarising, the proposed concept considers all factors that are relevant for solar energetic use in new building projects. Thus, the requirements in communes, which were found out in the user study, are fulfilled. For an efficient realisation, it is necessary to include the mentioned factors in a performant workflow. The user study has shown that instead of developing a software tool, it is also possible to provide a service. The majority of communes stated that they would also contract an external service provider with the calculation. The main steps include the modelling of the buildings, the calculation of the relevant factors and possibly an optimisation of these factors. An approach for a GIS-based realisation is presented in the following section.

5 Practical Realisation, Validation and Results

The criteria described in section 4 can be analysed to a large extent by using GIS software. In our first prototypical practical validation, the calculations of the orientation of the main building facades, the A/V ratio and the A/H ratio were realised by using the *ArcGIS Model Builder*. Generally, the solar radiation analysis can be performed by using the *ArcGIS Solar Radiation* tools or the *r.sun* module in *GRASS GIS*. After a first calculation, the factors can be optimised and recalculated in case of great solar losses.

Calculations were performed on a test area, which is a development plan area located in the city of Dortmund. The input data are usually dxf- or dwg-files containing typical elements of a development plan, which are specifications for building locations regarding building lines and set-back lines, eaves heights, roof pitches, locations of trees etc. In order to work with these data in *ArcGIS* the elements were converted to ESRI Shapefiles. For test purposes simplified assumptions for buildings and tree heights were made, which are described in the following. As a major city, Dortmund is representative of the conflict between creating enough living space on very small areas and solar energetic urban planning, which requires specified distances between buildings. The factors orientation, compactness as well as distance to neighbouring buildings and trees were calculated by using *ArcGIS* functions. Furthermore, a solar radiation analysis was performed. The following paragraphs present the results.

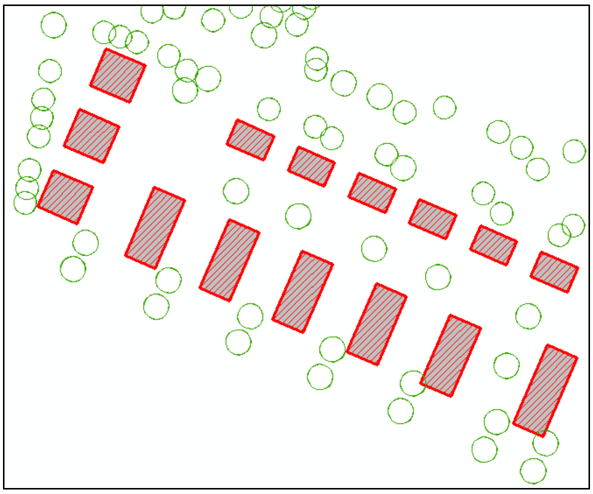

Fig. 2: Input data with planned buildings and tree positions.

Figure 2 shows the input data of an extract of the examination area with the planned buildings and tree positions.

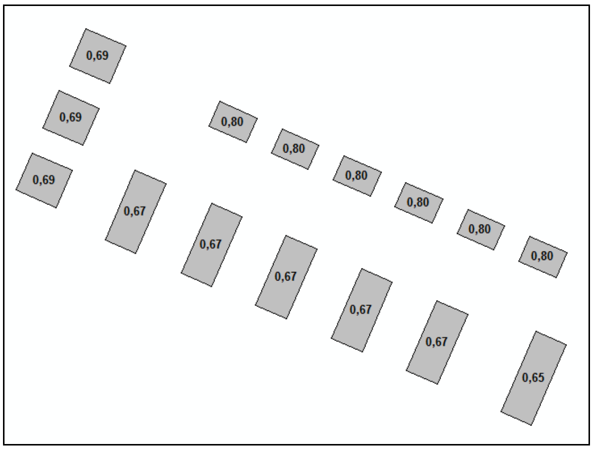

Fig. 3: Compactness – A/V ratio.

The building's compactness, defined by the A/V ratio (area over volume), is shown in Figure 3. It was calculated for each building assuming saddle roofs with eaves in a height of 3 metres and tops in an additional height of 4 metres. Only the building in the lower right corner complies with the limiting value of 0.65 m^{-1}. This is due to the relatively low building heights which are often higher in practice and should also be reconsidered in this planning.

The main building facade, which is the longest and closest to perfectly south-oriented building side, is displayed as a bold line in Figure 4. The facades whose orientation deviates more than 45° from south are highlighted in red. These buildings have to be optimised by performing a rotation. The minimum distance to neighbouring buildings and trees is dependent on their heights and defined by the A/H ratio. For instance, for 7 m tall buildings and a 2.7 fold building height, the minimum distance is 18.9 m. Assuming 8 m tall trees and a 2.0 fold tree height, the minimum distance is 16 m. Figure 4 illustrates these minimum distances as buffers around the main building facades with a width of 18.9 m and buffers around the centre of the trees with a width of 16 m. In particular, the spaces between the three buildings in the northwest part need to be enlarged. Trees have to be planted more economically and should especially not be placed south of buildings (cf. GORETZKI 1998).

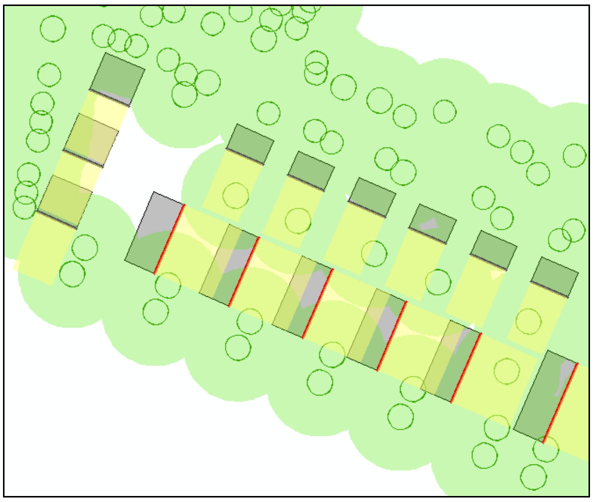

Fig. 4: Distance – A/H ratio.

Figure 5 shows the results of the solar radiation and shading analysis that was performed by using the *GRASS GIS* module *r.sun*. For this purpose, a DEM of the examination area with all planned and existing buildings as well as trees was created. PVGIS was used as the solar radiation database. Then, the global radiation within one year in kWh was calculated for the roof areas. The solar radiation is relatively high on the southern side of the roofs. It is only affected by trees. The next step is to perform the solar radiation analysis for the building facades. This can be done by calculating the solar radiation at the height of the windows considering the number of storeys.

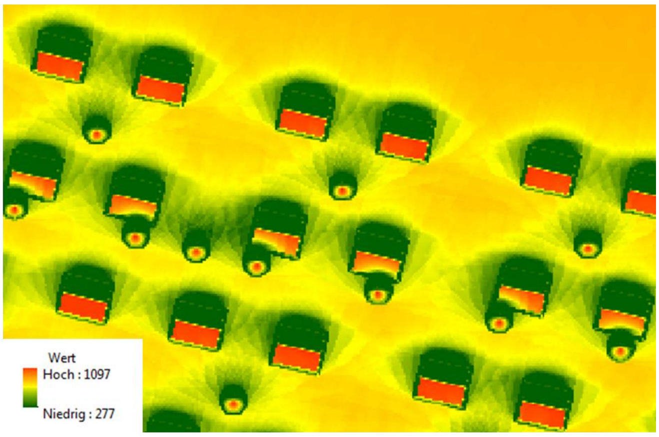

Fig. 5: Global radiation within one year in kWh.

6 Conclusion

As a consequence of a variety of geo-political and technical developments, we are currently witnessing an increasing commitment to renewable energy sources. Particularly in Germany, the percentage of renewable energy of gross power consumption has increased to 22.9% in 2012, mostly due to the Renewable Energy Law (Erneuerbare-Energien-Gesetz – EEG) (BMU 2013).

In effect, communes react to these developments by undertaking solar energetic examinations of new building projects (STADT AUGSBURG 2007, ENERGIEAGENTUR.NRW 2011). However, current research solely focuses on solar potential assessment for existing structures. Furthermore, available software solutions do not consider relevant factors for decentralised energy generation and savings right at the start of the analysis and planning of new buildings and urban areas. Additionally, existing analysis software is mostly inadequate and not sufficiently developed. This means that suitable software tools, which enable automated analysis and planning, are missing.

This paper presents a concept for solar energetic examination of new building projects with special regard to communes' needs. In a first step, we examined the particular requirements in communes. For this purpose, we developed a questionnaire, which focuses on assessing the requirements for the use of Geographic Information Systems (GIS) based software for planning new buildings and urban areas under thorough consideration of solar energetic aspects. Our work contrasts or extends previous work in two ways: first, by considering new building projects instead of existing built structures; and second, by focusing on urban planning processes rather than on individual buildings.

The results of the survey show that only few communes perform solar energetic examinations of new building projects until now, although the interest and the need are widely present. Besides, the use of GIS plays an important role as almost all communes have experience with it. Therefore, the concept focuses on increasing the percentage of communes performing solar energetic examinations by developing a simple, understandable and easy to handle tool on the basis of GIS.

In a next step, we have pointed out the main aspects and factors of solar energetic examinations and validated them in a prototypical realisation. Even though the limiting values have not been accounted for in every way in our prototype, the test calculations show that solar energetic analyses are generally feasible with the help of GIS.

On the basis of the survey results, we developed a GIS-based software concept to support the expansion of renewable energies, which in turn requires consideration of numerous small, regionally spread energy sources. Our results show that GIS is likely to be a linking element between different parties involved into the planning process such communal planners, infrastructure operators, energy producers and political decision makers.

Moreover, the results of our research show that communes have a strong demand for software tools that support solar energetic examinations. This in turn requires far-reaching and transparent integration of citizens into planning processes. Thus, participation in the planning process and provision of sound information, for instance, in a WebGIS, is important for citizens. The advantages of solar energetic examinations lie in energy savings and CO_2 reductions, good image and marketing of the solar settlements, as well as competitive advantages.

Summarising, it can be stated that communes are able to influence the energy efficiency of new buildings through using GIS-based planning tools. Like this, climate protection concerns can be integrated early on in the planning process. Thus, the conditions for optimal usage of solar energy can be established right from the start instead of retrofitting existing structures in an artificially induced urban reshaping process.

References

BMU (2013): Erneuerbare Energien 2012. Daten des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit zur Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2012 auf der Grundlage der Angaben der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat). http://www.erneuerbare-energien.de/fileadmin/Daten_EE/Bilder_Startseite/Bilder_Datenservice/PDFs__XLS/hintergrundpapier_ee_2012.pdf, Accessed 03/13

BMWI; BMU (2012): EU-Effizienzrichtlinie und Erneuerbare-Energien-Gesetz – Ergebnispapier. Bundesministerium für Wirtschaft und Technologie und Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit. http://www.bmu.de/files/pdfs/allgemein/application/pdf/ergebnispapier__eu-effizienzrichtlinie.pdf, Accessed 03/13

BRÜCKNER, M.; LAKES, T. (2012): Solarpotenzialkataster als lokale Anwendungen im Kontext der europäischen Geodateninfrastruktur. In: gis.SCIENCE, Vol. 2/2012, pp. 83-90

CARNEIRO, C.; MORELLO, E.; RATTI, C.; GOLAY, F. (2009): Solar Radiation over the Urban Texture: LIDAR Data and Image Processing Techniques for Environmental Analysis at City Scale. In: Lee, J.; Zlatanova, S. (Eds.): 3D Geo-Information Sciences. Berlin-Heidelberg: Springer, 2009, pp. 319-340

ENERGIEAGENTUR.NRW (2011): 100 Klimaschutzsiedlungen in Nordrhein-Westfalen – Planungsleitfaden. Düsseldorf. 2. Aufl. http://www.energieagentur.nrw.de/_database/_data/datainfopool/100_KSS_Planungsleitfaden_2011.pdf, Accessed 03/13

ENEV (2009): Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Energieeinsparverordnung – EnEV). http://www.enev-online.org/enev_2009_volltext/index.htm, Accessed 03/13

GORETZKI, P. (1998): Planen mit der Sonne - Arbeitshilfen für den Städtebau. Ministerium für Arbeit, Soziales und Stadtentwicklung, Kultur und Sport des Landes Nordrhein-Westfalen und Stadt Köln, 1998

HÖFLE, B. (2012): Nachhaltige Stromerzeugung - Geoinformationen optimieren Solaranlagen. In: Ruperto Carola Forschungsmagazin, Vol. 1/2012, pp. 44-46

HÖFLE, B.; JOCHEM, A. (2012): 3D Laserscanning Punktwolken und GIS - Aktuelle Entwicklungen. In: gis.SCIENCE, Vol. 25(2), pp. 91-100

IBM SPSS STATISTICS (2012): SPSS Statistics. http://www-01.ibm.com/software/analytics/spss/products/statistics/, Accessed 03/13

JOCHEM A.; HÖFLE B.; RUTZINGER M. (2011): Extraction of Vertical Walls from Mobile Laser Scanning Data for Solar Potential Assessment. In: Remote Sensing, Vol. 3(4), pp. 650-667

KOMMUNALES KOORDINIERUNGSGREMIUM GDI-DE (2013): Einsatz von Geoinformationen in Kommunen. http://www.dstgb.de/dstgb/Kommunalreport/Einsatz%20von%20Geoinformationen%20in%20Kommunen/Ver%C3%B6ffentlichungsversion%20KoKo-Studie%2022.03.2013.pdf, Accessed 04/13

KROPP, C. (2010): Der Weg zum europäischen Supergrid: Notwendige Infrastrukturerweiterungen und Probleme der Implementierung. Bachelor Thesis, Institute of Geography, Ruprecht Karls University Heidelberg

NORM DIN 5034-1: 2011-07 (2011): Tageslicht in Innenräumen – Teil 1: Allgemeine Anforderungen. Berlin: Beuth, 2011

PVGIS (2013): Photovoltaic Geographical Information System. http://re.jrc.ec.europa.eu/pvgis/, Accessed 03/13

SOSCI SURVEY (2012): SoSci Survey. https://www.soscisurvey.de/, Accessed 03/13

STADT AUGSBURG (2007): Klimaschutz und Stadtplanung Augsburg – Leitfaden zur Berücksichtigung von Klimaschutzbelangen in der städtebaulichen Planung und deren Umsetzung. http://www.energieatlas.bayern.de/file/pdf/782/Leitfaden_Klimaschutzundstadtplanung_Augsburg.pdf, Accessed 03/13

SÚRI, M. AND HOFIERKA, J. (2004): A new GIS-based solar radiation model and its application to photovoltaic assessment. In: Trans. GIS 2004, 8, pp. 175–190

UMWELTBUNDESAMT (2008): Environmental awareness among Germans is high. http://www.umweltbundesamt.de/uba-info-presse-e/2008/pe08-085_environmental_awareness_among_germans_is_high.htm, Accessed 03/13