City of Graz Solar Roof Cadastre

GIS-Based Local Analysis for Solar Plants – a Planning Tool

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Abstract

In the "**K**ommunales **E**nergie**k**onzept" (KEK 2020) (Municipal Energy Plan) of the City of Graz, special attention is paid to the using of solar energy. In order to intensify well-aimed expansion of thermal solar plants, a process acquiring and assessing the solar energy potential of the house roofs in Graz was developed. The Municipal Surveying Department carried out the project in co-operation with the Environmental Department of the City of Graz by applying the municipal **G**eographic **I**nformation **S**ystems (GIS).

Based upon True Orthophoto, the Digital Surface Model (DSM) and the photogrammetric measured roof landscape ,the shading, the roof orientation, the roof pitch as well as the size of the suitable roof areas of each building can be acquired. Among the 14 million square metres of roof area, 40 % are "very suitable" or "suitable" for solar plants and yield a possibly usable thermal solar potential to the amount of approx. 2,000 GWh every year. This approximately corresponds to the overall energy needs of Graz relating to heating and hot water. Automated selective evaluation makes it possible to specifically support erection of large-scale solar plants by providing consulting services and preliminary studies. Thanks to this process, it is, at any time, possible also to study the roofs in terms of photovoltaic systems.

1. Basic Data

Suitable locations for solar power plants are identified on the basis of the digital image data provided by the Aeroflight GRAZ 2007. A continuously digital workflow is guaranteed for the first time by simultaneous acquisition provided by PAN and multispectral recordings using the large sized digital air picture camera UltraCam X (Vexcel Imaging), processing of image data that is largely automated, establishing the photogrammetric follow-up products, project related analysis and acquisition of results. These are the most important parameters:

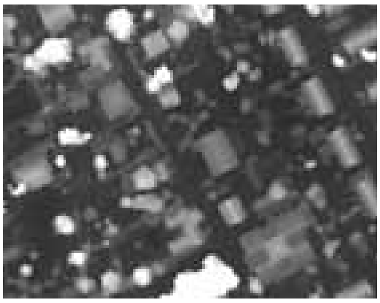
- recording area: the whole municipal area, incl. the closing neighbouring areas;
- number of images: approx. 3,600 (approx. 14,500 x 10,000 pixels/image);
- longitudinal overlapping: ~ 80%; transverse overlapping: ~ 60%;
- high geometric accuracy
- resolution on the ground: 8 cm
- recording moment: vital vegetation (full foliage), September 2007

1.1. Digital Surface Model - DSM

An important follow-up product of the Digital Aeroflight 2007 is the "Digital Surface Model - DSM " (cf. Fig. 1).

In contrast to "Digital Terrain Model – DTM", DSM does not only describe the altitude of the ground surface but also the heights of the natural and artificial objects above ground, e.g. vegetation and buildings. Based upon the data records in original resolution, DSM is derived and generated in a grid size of 20 x 20 cm and with an altitude accuracy of ~ +/- 15 cm.

At this resolution, the smallest structures, such as roofs and dormer windows, will become visible and can thus be considered when identifying the solar potential. Approx. 3.1 billion pixels are necessary to cover the whole municipal area..



Due to the basic data in the grid format and the analyzing methods described below, the data record will be saved in the municipal geographic information system ArcGIS (ESRI) as ESRI Integer GRID. The memory available to the whole digital surface model amounts to about 20 GB.

Fig. 1: Digital surface model of the City of Graz in the 20 x 20 cm grid, section of 180 * 140 m

1.2. Photogrammetric measured roof landscape

In the Surveying Department of the City of Graz, the position and altitude of all recordable nature will be acquired by means of photogrammetry (image measurement). Not only buildings with the averaged roof areas but also green spaces with their vegetation, water bodies, paved surfaces, etc will be measured.

This data is the basis for any types of planning work done by municipal specialized departments and private planners. For identifying the possible solar areas, the roof landscape acquired by means of photogrammetry are implied.

Fig. 2: Roofscapes evaluated photogrammetrically

2. GIS Analyzing Method

In order to obtain a realistic value for annual useful energy in kilowatt hours, the "Spatial Analyst" will be used in addition to the general analytic functions of the Geographic Information System ArcGIS. The Spatial Analyst supplements the GIS by adding complex grid functionalities. Based upon the GIS tools, the Municipal Surveying Department has developed an automated analyzing method, which makes it possible to determine shading effects, the angle of pitch of a roof, exposure as well as the size of the usable and coherent roof area.

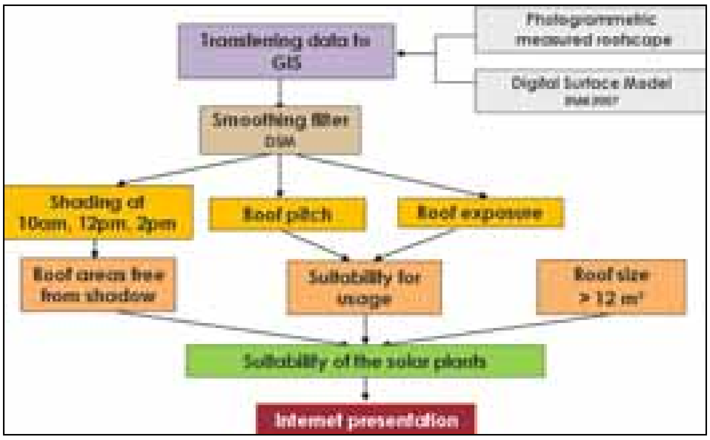


Fig. 3: Workflow of solar calculation

2.1. Shading

Shading caused by adjacent buildings, trees or chimneys play a decisive role for solar plants. Therefore, it is absolutely necessary to consider them during planning and exclude shaded roof areas right from the start. In the first operating step, shading will be determined on the basis of the digital surface model covering the whole area.

Shading can be calculated at any place at any time. This requires the geographic latitude, the time of the day and year and the position of the sun, which results from the azimuth and altitude angle of the sun. The azimuth states the angle between the projection of the sunbeams on the horizontal level and the geographic southern direction. The altitude of the sun is the angle between the horizontal line and insolation. At 47° N, it will, at noon, take on a value between 19.5° (lowest position of the sun) and 66.5° (highest position of the sun).

The position of the sun can be read from the relevant chart showing the positions of the sun (cf. Fig. 4). Shading will be calculated for September 21st at 10, 12 and 14 o'clock. The position of the sun on September 21st corresponds to that on March 21st (equinox).

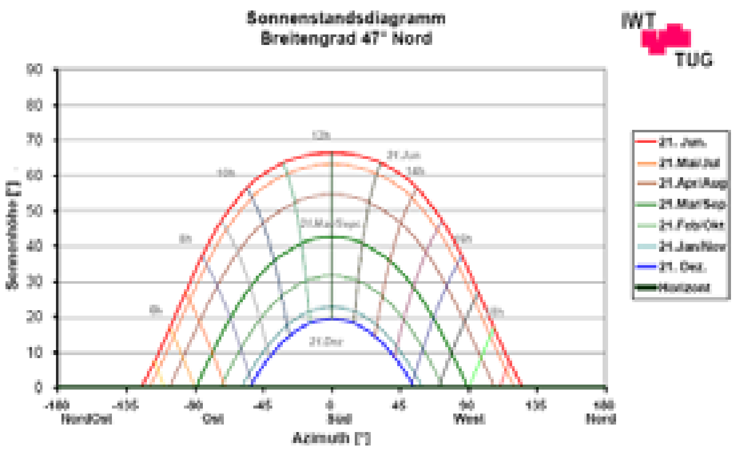


Fig. 4: Chart showing the positions of the sun for the geographic latitude of Graz (Source TU-Graz, Institute for Heat Technology)

The acquired shading areas will be removed from the overall roof area so that the result of this calculating step will be formed by the roof areas that are completely free from shadow from March 21st to September 21st at 10, 12 and 14 o'clock.

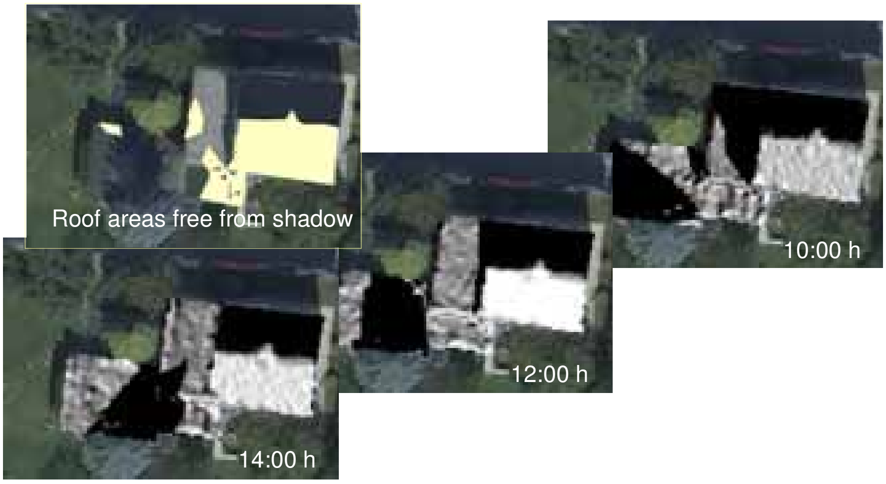


Fig. 5: Shading at 10, 12 and 14 o'clock and the roof area free from shadow

2.2. Mask of the building

For evaluation of the solar potential as such, it is no longer the whole DSM that will be needed. Instead only the buildings will be needed. Besides, there are attempts to minimize the computing times. Therefore, a mask of the building will be created. This mask will be generated on the basis of the outermost limiting lines of the roofscapes evaluated photogrammetically. The mask of the building will be used on the DSM as well as for the results of acquisition of the shadow.

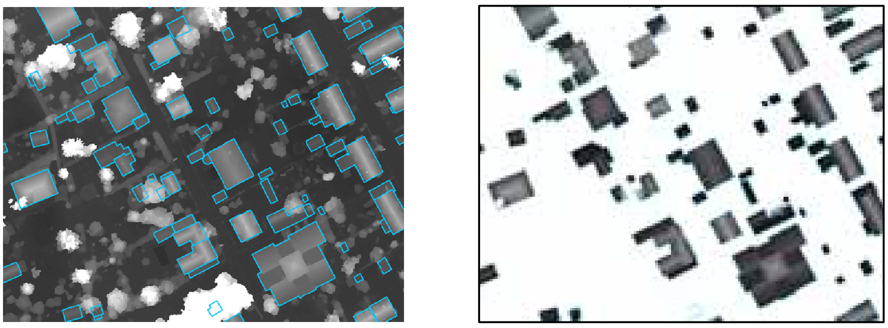


Fig. 6: Mask of the building

2.3. Roof exposure / pitch

In order to ensure the energy output of a solar plant is as high as possible, the orientation of the roof is decisive. Optimal orientation directly shows towards the South. The energy yield that will be possible then will be set to 100 %. Yet even if there is a deviation to the East or West, high yields can still be achieved.

In order to determine the orientation of the roof, the deviation of the roof surface from northerly/southerly direction will be determined. As there is no orientation in case of flat roofs, the result will be an inhomogeneous area.

Besides the orientation of the roof, the pitch of the roof is decisive for the solar use of roofs. In order to make sure insolation can be used as well as possible, it should irradiate the solar plant in the right angle as far as possible. Therefore, a roof pitch of 30° to 50° is ideal for thermal solar plants used for hot water treatment in the conurbation area of Graz.

The roof pitch results from the angle of the horizontal line to the roof in degrees. The maximum pitch of a pixel will be derived from the area around 3 x 3 pixels. In spite or just because of the high data quality of the digital surface model (20 x 20 cm grid, altitude accuracy of ~ +/- 15 cm), there will be inhomogeneous areas when calculating the pitch. In order to improve homogeneity (smoothing), a low-pass filter (mean-value filter with 5 x 5 grid cells) will be used.

2.4. Classification

In the next step, solar suitability will be classified on the basis of the pitch and orientation. In co-operation with the Environmental Department and SOLID, a company based in Graz, the roof areas will be classified as “very suitable” (Grade 1) or “suitable” (Grade 2). The classification of “very suitable” will be given to the roof areas representing a combination optimal for use of solar energy.

Flat roofs will generally be classified as being “very suitable”. For in principle installation of the solar plants at an optimal southerly orientation is assumed for flat roofs.

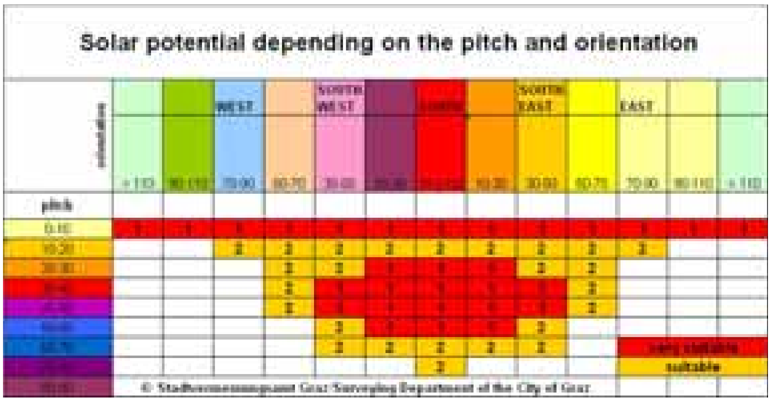
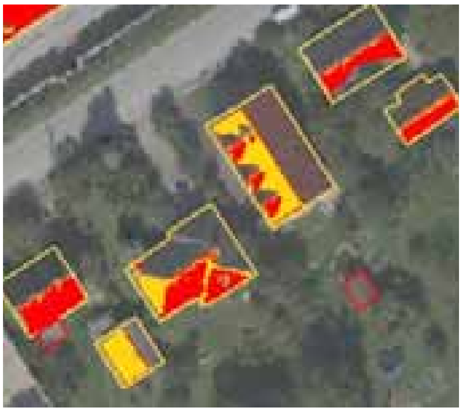


Fig. 7: Solar potential depending on the pitch and orientation (1 = very suitable, 2 = suitable)

3. Results

After the roof areas have been classified, they will be blended with roof areas free from shadow. The result will be formed by the roof areas that are completely free from shadow from March 21st to September 21st at 10, 12 and 14 o’clock and whose solar potential is classified as being “very suitable” or “suitable”. For erecting solar plants, a roof area of at least 8-12 m² is useful. In order to model a practice oriented result, only the solar areas whose minimum size amounts to 12 m² (cf. Fig. 8) will be stated to be usable.



For determining the usable solar output, the roof areas classified as being “very suitable” will be defined as having 360 kWh/m²a and those classified as being “suitable” as having 300 kWh/m²a (Energy Division, Environmental Department of Graz).

These values are common yields of useful heat while considering the local global radiation and the efficiency of thermal solar plants.

Fig. 8: Suitable solar areas (red roof areas: classified as being very suitable; orange roof areas: classified as being suitable)

Among the 14 million m² roof area of the City of Graz, 45 % are suitable for thermal solar plants. As the rules of the Act protecting the Old City are so restrictive, roofscapes in the areas subject to the protection of the old city may only be changed to a limited extent.

If this circumstance is taken into account and if the relevant roofscapes are excluded from final calculation, 40% of all roof areas of Graz will still be suitable for erecting solar plants. If the whole potential were used, energy to the amount of approx. 2,000 GWh could be won.

4. Internet presentation

Since January 1, 2010, the Cadastral Map of Solar Roofs can be called in the internet for the whole municipal area on the server showing the geographic data (www.gis.graz.at).

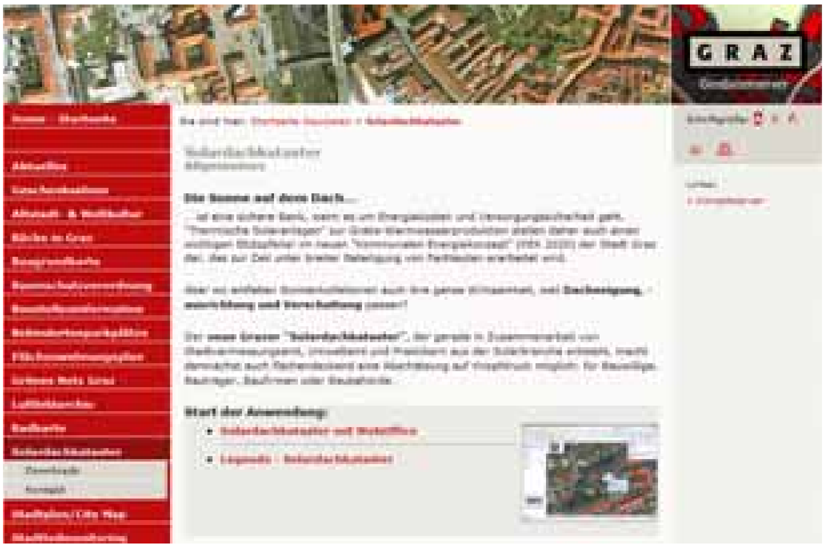


Fig. 9: Server showing the geographic data of the City of Graz

Each citizen of Graz has the opportunity of looking for his/her building and inquiring his/her personal solar potential by using this address. The building looked for will be marked on the air picture and shown in colour depending on the assessment.

Fig. 10: www.gis.graz.at

The following information can be called for each building:

- possible solar area;
- usable energy potential;
- note
  - not suitable, or the solar area is smaller than 12 m²
  - roofscape worth preserving
- link to the Environmental Department (subsidies/consulting)

5. Use and outlook

Since 1991, the City of Graz has, again and again, taken concrete initiatives for expanding solar energy in the municipal area of Graz even more.

In this context, the stakes are mainly put on

- consulting (further training of the professionals, feasibility studies for solar projects, …);
- subsidizing solar plants since 1991; in addition to subsidies granted by the Province of Styria, the solar areas for private persons are subsidized with € 100/m² by the City of Graz;
- developing model projects for solar cooling;
- identifying and analyzing the potential by using the Cadastral Map of Solar Roofs, even for citizens

The main advantages yielded to the City of Graz are reduction of the emissions, actively counteracting the problems relating to PM12 (particulate matter), reinforcing technological competence and increasing local value added. However, the chance to position the city as a solar city all over Europe and to come one step closer to meeting the ecological requirements by the EU by intensifying solar energy also is used. (SCHLEMMER, P.).

In Graz, many solar plants have already been built in the last few years. Some large-scale solar plants are worth mentioning. Examples: supply of the housing estate on the Berliner Ring with a collector area of 2,480 m² (in case of excessive heat, the local heat network will be fed), the biggest solar plant of Central Europe with 4,062 m² at "Wasserwerke Andritz" and a solar area of 4,000 m² at AEVG-Abfallentsorgungs- und VerwertungsGmbH (Waste Disposal and Recycling).

In the "**K**ommunales **E**nergie**k**onzept" (KEK 2020) (Municipal Energy Plan), it is, in co-operation with local energy providers and utilities, that well-aimed erection of solar plants is intensified on the basis of the evaluation of the Cadastral Map of Solar Roofs. The Environmental Department of the City of Graz actively addresses the owners of big potential solar areas by offering large-scale consulting services.

In a first step, the buildings that are "public buildings" in the broadest sense of the term are being studied for useful use of solar plants. This is being done for residential buildings owned by the city as well as for other objects whose hot water needs are high, e.g. sports facilities.

Utmost attention is paid to substitution of electric current in decentralized hot water treatment facilities. Since July 01, 2010, it has therefore also been conversions to hot water treatment using district heating with the option to incorporate solar plants have been subsidized.

Fig. 11: Studied living estate in the "Harmsdorfsiedlung"

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