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Solar potential in existing urban layouts—Critical overview of the existing building stock in Slovenian context

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HIGHLIGHTS

- New Slovenian legislation regarding minimum insolation of building envelope.
- Seven typical urban layouts were analysed.
- Requirements and rules of good practice result in adequate insolation.
- Duration of insolation is highly dependent on the specifics of each case.

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ABSTRACT

In recent years implementation of sustainable building design in the EU has become one of the key issues in reducing energy dependence. In this context efficient use of solar potential incident on building envelope is essential. The goal of the study is to evaluate the influence of interventions required by the new Slovenian legislation and to propose general site planning guidelines. Special emphasis is devoted to the existing building stock, which is due for refurbishment. The study is carried out on the basis of seven typical urban layouts, which are assessed according to the shape of layout, density, building orientation and design. The calculations are carried out with the program SHADING. The study showed that the existing layouts are not as problematic as had been expected and that form and orientation of buildings present a major challenge. Nevertheless, the quality and the duration of insolation are highly dependent on the specifics of each case. The study showed that by respecting the basic rules of good practice in conjunction with the existing requirements no major changes in the existing design principles are needed.

1. Introduction

In the recent years implementation of sustainable building design in the EU has intensified. The recast Directive on energy performance of buildings (EPBDr, 2010) presents the reboot in this field. Considering renewable energy potentials, Slovenia has a medium-sized solar potential, which is underutilized. According to Slovenian Environmental Agency, yearly sum of global irradiation on horizontal plane is approximately 1120 kWh/m^2 (ARSO, 2012) while Joint Research Centre Institute for Energy and Transport, Renewable Energy Unit (PVGIS, 2012a), states a slightly higher value of 1250 kWh/m^2.

The goal of the study is to propose general site planning guidelines for efficient use of solar potential incident on building envelope in order to enhance the use of solar energy. The existing building stock, which is due for refurbishment, is of special importance, because this might close the gap between the existing situation and future nearly zero energy buildings (nZEB) by using solar technologies (direct solar gains, solar collectors (SC), building integrated photovoltaic panels (BIPV), etc.) in urban built environments (La Gennusa et al., 2011). According to PVGIS (2012b), the average yearly global irradiation incident on optimally-inclined PV modules placed in urban areas is approx. 1425 kWh/m^2. Solar potential can be harvested either on individual buildings or on larger urban scale. Lund (2012), who is addressing the problem of large-scale urban renewable electricity schemes in Helsinki (a climate that has much less solar potential than Slovenia), established that with optimal electricity-to-thermal energy strategies and energy management, a 40–65% solar fraction of yearly electricity could be reached. In the Helsinki climate with wind power coinciding with the seasonal peak load, renewable energy sources (RES) may satisfy more than 30% of all annual energy demand and more than 70% of all annual electricity demand.

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The study on global irradiation and solar electricity potential for Slovenia, which is currently underway, will give some general answers to the question where to install PVs (Huld et al., 2010). However, on smaller scale the effect of building envelope shading has to be assessed as it can have a dominant effect on the quantity of utilized solar energy.

The role of urban setting on the energy performance of buildings is often overlooked, although it can greatly influence the building's need for heating, cooling and lighting (Futcher and Mills, 2013; Capeluto, 2003) and its potential for solar energy utilization (Bojić and Blagojević, 2006). As already established by Karteris et al. (2013), determining the actual solar potential for applications in the complex urban environment is a difficult task. According to their findings, the solar utilization roof factor was in the majority of the examined buildings only between 25 and 50%. Kurokawa (2001) points out that, when a large number of PV systems are introduced in an area, PV electricity will become very significant and overall optimization may be required for the total area.

In the recent years a lot of work has been done in the field of assessment of solar energy utilization. Gadsden et al. (2003) developed the underlying methodology of a solar energy planning (SEP) system for energy advisers and policy makers. The methodology predicts the baseline energy consumption of domestic properties and determines the potential for its reduction, using the three key solar technologies, i.e. passive solar design, solar water heating and PV systems. Okeil (2010) states that a holistic approach to energy efficient building forms is needed. He proposes a Residential Solar Block (RSB) which can maximize solar energy falling on façades in winter, thus maximizing the potential of solar energy utilization. Mardaljevic and Rylatt (2003) proposed a novel approach for evaluating the total annual/monthly irradiation incident on building façades in urban settings with the help of "maps" of annual/monthly irradiation. Sanchez de la Flor et al. (2005) proposed a new methodology for the calculation of the direct, diffuse and reflected incident solar radiation on all types of surfaces, either in open urban environments or inside buildings. Capeluto and Shaviv (2001) proposed the introduction of solar rights (SRE) and solar collection envelopes (SCE) to protect solar rights of existing buildings and maximize solar exposure of the envelope and systems of the designed new building. Yezioro et al. (2006) elaborated design guidelines for appropriate insolation of urban squares. In the past the basic solar exposure analyses for Slovenia were carried out by Kristl and Krainer (2001, 2004, 2006), but we have to bear in mind that since then the legal requirements in Slovenia have changed. The actual analyses of how much solar radiation can be harvested in actual urban settings and what are the best strategies for various types of urban layout have not been done yet.

The current study, partially executed in the framework of the activities of the Competence Centre Sustainable and Innovative Construction (KC TIGR, 2010), considers seven typical neighbourhoods in Slovenia. Potential duration of solar exposure on building envelope was calculated with SHADING (Yezioro and Gutman, 2009) plug-in for Google SketchUp (Google Inc., 2011). Solar exposure of building envelopes was assessed on the basis of specific influential factors: density, orientation and shape. Special attention was paid to the relative influence of roofs and façades. We expected that some of the studied urban layouts would not reach the minimum required solar exposure.

2. Legal background

2.1. European policy

In January 2007, the Commission proposed the well-known comprehensive climate and energy package containing targets of 20–20–20% reduction of energy consumption and greenhouse gas emissions, and increased share of renewables by 2020 (LGCC, 2007). In the years that followed several documents targeted at the reduction of energy use in building sector were put forward. Presently, besides EPBDr, there are also other directives dealing with energy aspects in buildings, e.g. Ecodesign requirements for energy-using products Directive (ERED, 2005), Energy efficiency Directive (EED, 2012), Regulation for harmonised conditions for the marketing of construction products (REG305, 2011), and the Directive on the Promotion of the use of energy from renewable sources (PUER, 2009). Relevant provisions on buildings can also be found in the Sustainable Production and Consumption and Sustainable Industrial Policy Action Plan (PAP, 2008). All of the stated documents constitute a system of legal instruments that promote sustainable building design.

The goal of the above mentioned legislative documents is to achieve reduction of energy use and increase the use of renewables in buildings. EPBDr acknowledges that "despite the actions already undertaken, very large cost-efficient energy saving potential remains unexploited. This means that a lot of the potential social, economic and environmental benefits at national and EU level are not fully taken advantage of. This is due to the complexity of the sector and the existence of market failures, but also to some limitations of the wording and scope of some provisions of the current EPBD and the low level of ambition of its implementation by some Member States." (EPBDr, 2010).

2.2. National legislation

Requirements regarding building positioning on plots, solar exposure and allowed overshadowing in Slovenia are regulated in several documents, first in the Construction Act (ZGO-1, 2002) and the Spatial Planning Act (ZPNacrt, 2007), then in several regulations and ordinances and finally in norms, recommendations and municipal acts. For easier understanding the most significant ones are presented below.

Since 1988 insolation in Slovenia has been regulated by the Obligatory instruction on minimum sanitary and technical requirements (Republic Health Inspectorate, 1988), which encourages the rule of good practice in the form of minimum required duration of insolation in living spaces. The majority of layouts presented in this study were built according to this rule. Insolation in the centre of a living room window had to be checked during four reference days in a year and had to reach at least 1 h on December 21st, 3 h on March 21st and September 21st and 5 h on June 21st. These requirements have been unconditionally respected and they ensure the above mentioned solar exposure duration to residential buildings. Designers have tried to fulfil them in any possible way and sometimes the required duration was reached by adding up several short time intervals of insolation received through the gaps between the neighbouring buildings. The new Slovenian Rules on efficient use of energy in buildings (PURES 2010, 2010), supported by the Technical Guidelines, TSG-1-004:2010—Efficient energy use (TSG4, 2010), require longer solar exposures and are at the same time more flexible.

PURES 2010 and TSG4 are intended to change the existing practice and introduce more Passive Solar Architecture (PSA) features as well as PV and SC systems into the existing building practice in order to approach to the nZEB goal. TSG4 requires that the "collecting area" of a building has to be insolated (average) 1 m above the ground (lower areas are not considered due to natural and built obstructions) at least 2 h on December 21st (allowing for solar azimuth South $\pm 30^{\circ}$). The azimuth restrictions were set in order to enable harvesting of solar energy during short winter days at its peak and to avoid low incidence angles with small potential to be included into calculation. On the equinox (March 21st and September 21st) at least 4 h (allowing for solar azimuth South $\pm 60^{\circ}$) and on summer solstice (June 21st) at least 6 h