Zurich, June 15-17 2016
Sustainable Built Environment (SBE) Regional Conference

Expanding Boundaries:
Systems Thinking for the Built Environment

SOLAR ENERGY AVAILABILITY IN URBAN DENSIFICATION PROCESS IMPACT ON EXISTING BUILDINGS IN A SWISS CASE STUDY

C.S. Polo López[1]*, M. Sala[2], F. Frontini[1], L. Tagliabue[3], E. De Angelis[2], G. Pansa[2]

[1] University of applied sciences and arts of southern Switzerland SUPSI, Trevano, CP 105, CH-6952 Canobbio, Switzerland

[2] Politecnico di Milano, Architecture, Built environment and Construction Engineering Department, Via Ponzio 31, 20133 Milano, Italy

[3] University of Brescia, Department DICATAM, Via Branze 43, 25123 Brescia, Italy

*Corresponding author; e-mail: cristina.polo@supsi.ch

Abstract

Urban densification is a growing phenomenon that is strongly changing the interaction between existing buildings and the surrounding environment. As example, in Switzerland, the Cantonal Director Plan, expected for the next years, will change the urban density allowing to raise the three to four floor high buildings now separated by not too wide streets, to get over up to eight floors, without modifying the width of street layout. The paper deals with a case study located in Paradiso municipality, part of Lugano's settlement (CH) where the impact of the future buildings on pre-existing buildings, especially on the historical heritage has been quantified to understand the energy fallout by different points of view (i.e. solar energy availability, daylighting, energy saving, comfort and energy production through active solar systems, etc.). The paper focuses on a phase of a wider project aiming to evaluate the complexity of energy performance change in buildings and provide guidelines of intervention to assess the suitability of urban development solutions in dense urban context.

Keywords:

Architecture; building and planning; Energy technologies; Heritage buildings

1 INTRODUCTION

The rational use of energy towards greater efficiency and the reduction of climate altering gas emissions, the transition towards autonomy and self-sufficiency through renewable energy together with the energy supply issue are aspects that need to be considered when designing buildings and urban centres. Urban policies, local authorities and many communities recognize the economic and environmental benefits of dense urban environments and at the same time global energy stated goals for the near future are pushing for a greater improvement in energy efficiency in the building sector considering also the benefits of local renewable energy, generally, and solar energy, specifically [1]. The process of land planning and urban development requires long timeframes that are sometimes in opposition to the rapidity of these changes favoured by energy policies at the national and global level. In particular, urban densification policies can influence the energy demand and the solar availability of pre-existing buildings but especially on the protected heritage. Urban planning strategies determine the possibility to exploit solar irradiation as solar passive/active, daylighting, human comfort, etc. In the same way, urban densification can influence the building energy demand and building thermal performance, the level of conservation of existing buildings (in particular historical buildings) with also implications in the urban microclimate [2].

The opportunity to use the solar radiation, the natural lighting and ventilation in order to reduce energy dependency (for heating, cooling and lighting purposes) and to assure comfort, could be compromised in an urban environment with a fast, dense and excessive growth. The urban pattern and the building configuration can modify key aspects that are related to the rational use of

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_37, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

natural and environmental resources. The need to accurately quantify these effects is a strategic factor for predicting decreases in solar availability to understand the actual impacts to drive the corrective measures, if possible, and to pursuit a methodology of analysis that defines recommendations and theoretical principles. Researchers investigating these aspects can strongly support planners to achieve this objective to enact standards related to solar exploitation assessing the better way to integrate solar energy aspects, overtaking barriers towards solar rights definition [3].

2 DATA AND METHODS

At urban level in the Ticino Canton, urban densification strategies are underlined among the objectives of the Cantonal Director Plan (Flächennutzungsplan) [4]. Lugano Paradiso district is currently undergoing a profound change towards densification of the urban environment with the new master plan now in act. With the intent to revitalize the city centre, the new Plan already underway drives major changes on existing urban development patterns. The detailed plan of the common centre (PPCC, last update of the plan was published in May 2011, endorsed by the State Council in June 5, 2012) defines maximum volumes footprint to nine floors and contiguity mandatory with closed and compact urban fabrics, instead of the traditional division of land parcels. This research project, related on a real case-study, investigates how urban modifications, in particular urban densification policies, can influence the energy behaviour, the solar availability and comfort of pre-existing buildings, in particular on the protected heritage. Four protected heritage buildings were identified in the area: B.1 Palace Riva Paradiso (A4905); B.2 Hotel Victoria (A4906); B.3 Palace G. Guisan Street (A4907); B.4 Posthotel Simplon (A4908).

The paper focuses on a phase of a wider project, aiming to evaluate the complexity of energy performance change in buildings and provide guidelines of intervention to assess the suitability of urban development solutions in dense urban tissue [5]. Three aspects that will be addressed are described in the following sections.

2.1 Solar irradiation availability

Evaluation of the impact of the new buildings height on existing and historical buildings through the analysis of solar irradiation availability and the assessment of the human comfort in urban environment.

2.2 Human comfort assessment in urban environment

Identification of the differences between the current scenario and the future aspect of the city referred to the capacity of the buildings to use solar energy for thermal passive conditioning and daylighting purposes.

2.3 Energy efficiency of pre-existing buildings affected by urban modifications

The aim is to highlight strategies for harmonizing the energy needs of the buildings considered as a part of an urban context (new and existing buildings and historical buildings as part of this second category) to which the plan will be applied. The analysis has been carried out on multiple levels comparing the new scenario with the existing scenario and considering the effects of the loss of sky factor and the energy consumption in winter and summer due to thermal and lighting needs. To better assess the real impacts of the new dense urban plan, a structured analysis with dynamic simulation tools in combination with analytical studies have been regarded as crucial.

3 RESULTS

A comprehensive study of the urban area of the City Centre of Paradiso has been made. The results of this site survey allows to have a first estimation on solar urban transformation for each area. In particular, an exhaustive analysis is being carried out for each historical building in the area to define the solar obstructions in the current situation (Old Master Plan, Old MP) and future situation (New Master Plan, New MP).

3.1 Solar irradiation studies

To assess solar irradiation and shadow changes and the real impact of new and existing buildings quantifying the energy impacts in an urban context, solar simulation tools have been used to evaluate the different scenarios. Furthermore, simpler methods, as Sun-path diagrams can be used in combination with the simulation analysis completed using 3D Ecotect software. Solar obstructions can be read out directly on the diagrams, as the position of the sun in the sky at any time of the day on any day of the year can be read directly from the Sun-Path Diagrams. A more accurate analysis could be performed by using the HORIcatcher instrument developed by Meteotest. With a digital camera and a horizon mirror (spherical convex mirror) it is possible to register the horizon in the field quickly and efficiently in order to calculate limitations of the sunshine duration and irradiation due to obstacles and serves to obtain three-dimensional projections of the space projected in the mirror dome. Specific software calculates the sun's orbit, which is put in relation with the horizon and specific processing image software have been used to analyse the current urban status [6]. The analyses have been completed near the protected buildings under study, at ground level (bottom) where major impacts will be expected and at roof level (top) to assess the differences. Changes in solar irradiation at roof level will have an impact on

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_37, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

potential solar active installations, while at ground level, studying the effects on each façade will show the possibility to exploit passive solar strategies. Polar Sun-Paths, using the Stereographic Projection, have been used to pursue the differences from the old and the new scenarios as seen in the next figures (Fig. 1 and Fig. 2).

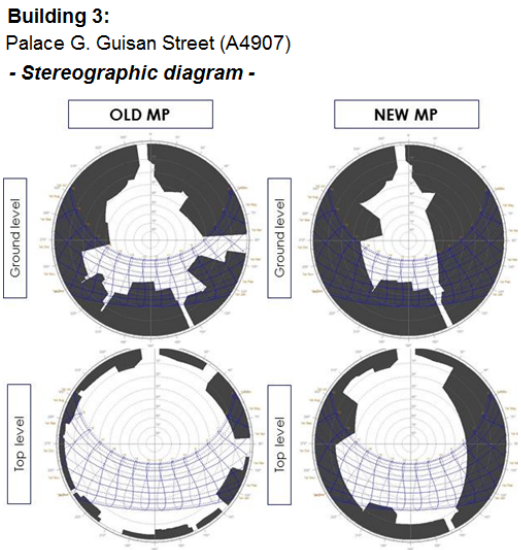

Fig. 1: Example of Ecotect sun-path diagrams (Building 3) calculated for the current master plan scenario (Old MP) and the new master plan scenario (New MP).

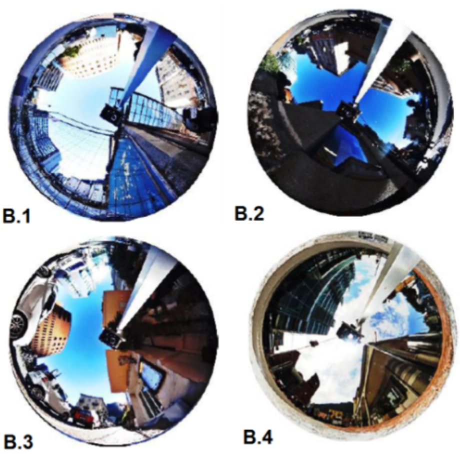

Fig. 2: Photo recorded by HORIcatcher device and modification in HDR format for each location studied near protected buildings.

By comparing the situation before and after, when the urban transformation will be definitely performed and the new master plan completed, it has been possible to calculate the percentage of solar obstruction (sunshine/shading) in each building studied, caused by the other buildings in the area (Fig. 3).

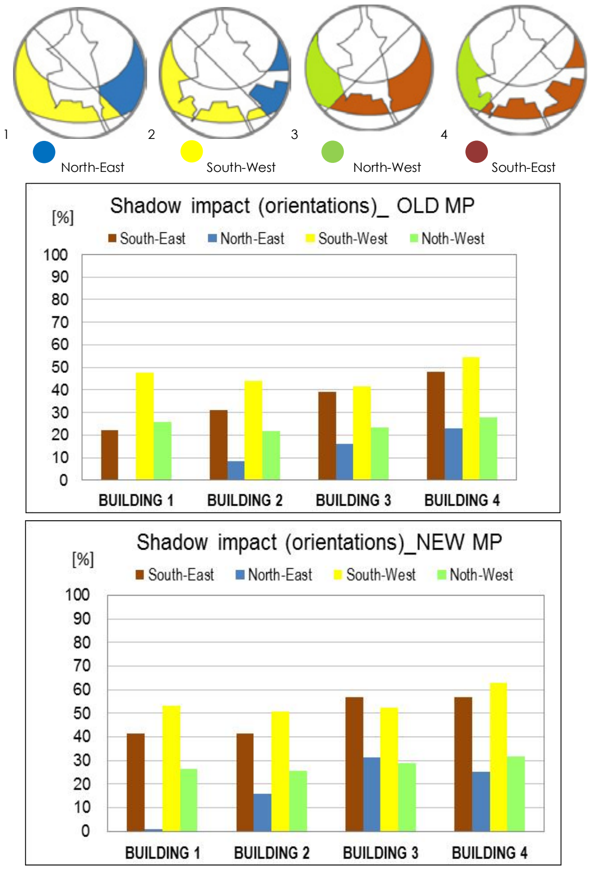

Fig. 3: Images and graphs show the results for different orientations (north-east, south-west and north-west, south-east): according to Fig.1, image 1 and 3 represent the current situation (Old Master Plan) and images 2 and 4 future situation (New Master Plan).

According to this analysis, the results show that for Building 1 there are slight differences by façades mainly because the surrounding urban area is already modified, while in contrast, the South-Est façade is highly affected. On the contrary, the greatest impacts are observed in Buildings 2, 3 and 4, as more changes are detected in their surrounding area in the future scenario. In these cases, at ground level and mainly in winter time, the situation becomes dramatic with very few hours of sunshine all year round. Particularly in the case of Building 3, for almost all façades (north-east, south-west, north-west or south-east) the situation worsens with the new master plan, increasing the percentage of shade from 6%, in the best case (North-West façade) to 17.5% in the worst case (South-Est façade).

3.2 Human comfort assessment

For the assessment of the human comfort differences in the area and bioclimatic techniques have been considered for calculating the ideal "comfort zone" for the specific location of Lugano to establish the aspects that compromise the fully exploitation of the environmental conditions and the possibility to use passive strategies for thermal conditioning. The meteorological climate data of

DOI 10.3218/3774-6_37, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

Lugano was used to perform this study, using average statistical data from the Federal Office of Meteorology and Climatology – MeteoSchweiz. With this data, bioclimatic diagrams have been developed using the CBA diagram (wellness adapted chart) settled on the basis of the Olgyay diagram, incorporating the main strategies of the Givoni diagram [7]. The results can be simplified and represented in an Isopleth map (Fig. 4a), hour by hour and month by month, where it is also possible to associate the areas representing the necessary passive strategies to reach comfort, identified in the CBA chart (1 to 6 zones,Fig. 4a). This graphic has been compared with the same type of diagram (month by month, hour by hour) showing the dynamic analysis results of solar irradiation simulations made with the Ecotect software for the old MP and the new MP (Fig. 4b).

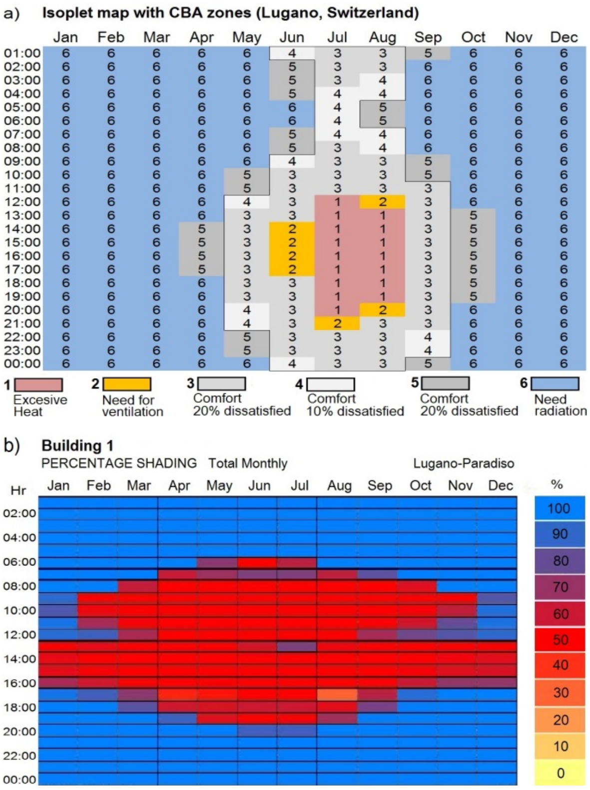

Fig. 4: a) Isopleth map with CBA zones (1-6) represented. The black line identified the period of time where shadow is necessary to prevent overheating; b) Shading graphic example calculated for Building 1.

The software allows evaluating and calculating, for each protected building, the total average percentage of shading generated by the lack of solar radiation due to the surrounding buildings. Areas plotted as number 6 and 5 in the first diagram (6: need of radiation and 5: comfort but, Predicted Percentage Dissatisfied, PPD-Index equal to 20%, based on the Fanger Comfort Model [8]) in order to take advantage of solar gains to maintain comfort should not be shaded (0% shade). By contrast, in the areas identified in Fig. 4, as 4, 3, 2 and 1 (4: comfort, PPD 10%; 3: PPD 20%; 2: need for ventilation and 1: excessive heat) should avoid excessive overheating due to solar radiation (100% shade are required if possible) to maintain comfort.

In the same way, the ideal comfort zone for the site can be also represented in the solar polar sun-path diagram (Fig. 5, where 5.a) represent the comfort zone in summer for Lugano Paradiso; 5.b) represent the comfort zone for winter time; 5.c) represent the solar obstructions assessment by photographic or analytical methods and the 5.d) represent the matching results between solar obstruction and comfort needs (in green are shown the positive effects, while in red the negative effects to the comfort zone). In this way, for example, the impacts could be easily visualized and measured by extrapolating conclusions of the diagrams when this area will be affected by obstructions of the surrounding environment.

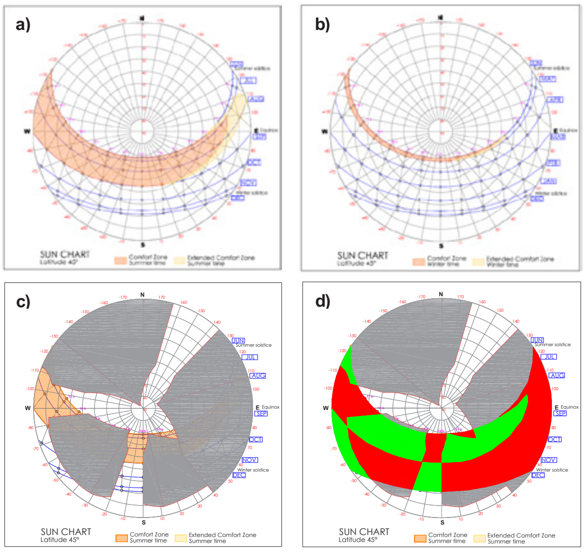

Fig. 5: Comfort zone calculated and represented in the solar polar sun-path diagram (stereographic projection) for Lugano area.

The results summarized in Fig. 6 and expressed in percentage, show that in the summer period although the discomfort predominates, in some cases (Building 3 and 4) the comfort increases slightly for the New MP scenario while only in Building 1 the percentage of thermal comfort time exceeds the discomfort. In winter time, however, for all buildings, the thermal comfort decreases while discomfort increases.

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_37, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

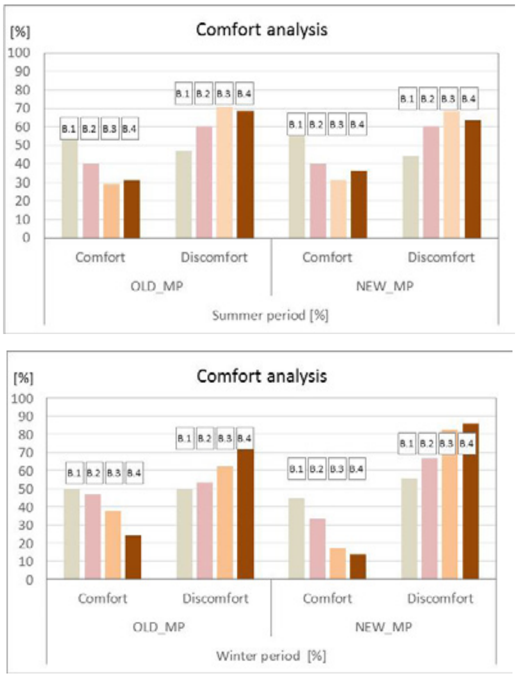

Fig. 6: Comfort zone impacts results for summer time and winter time calculated and represented in the solar polar sun-path diagram (stereographic projection) for Lugano area.

3.3 Energy efficiency assessment

In Switzerland, as in other EU states, the problem of energy saving is being supported and emphasized through strategies and regulations at a national and federal level [9, 10]. The cultural monuments, protected by the regulatory plan and immutable during the time, will suffer particular urban densification [11,12] and the need to quantify these effects is a key factor for predicting reductions in solar availability and energy demand of the building.

The analysis focused on Building 3 (Palace G. Guisan Street, A4907), the most influenced by the New MP. This residential building (total gross floor area 1.515 m²) was built between the end of sec. 19th and early 20th centuries. The building has three floors with an unheated basement and stairs. It has several openings (30% of the gross area of the façades) on all fronts and the main entrances are located across the main street (east), Guisan Street. The analysis has been performed with a plugin for SketchUp to perform detailed dynamic energy simulation with EnergyPlus [13] developed by Politecnico di Milano. The building has been simulated in the current context and in the hypothetical future context to quantify the damage in terms of energy demand due to the new context configuration [14] (Fig. 7).

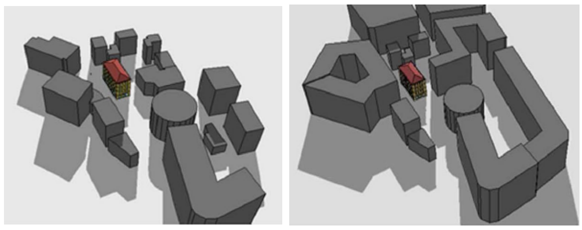

Fig. 7: Comparison between the models with the existing situation (left) and New MP (right).

The analysis considers different construction typologies referred to buildings' age to evidence how technological definition of the envelope affects the energy demand variation. The first construction detail (A) is a '50s wall made by 40 cm of stone with plaster. The second option (B) is a '70s wall with 20 cm of concrete with plaster and the third case (C) is a '80s wall adding to the second a 7 cm cork insulation layer (Fig. 8).

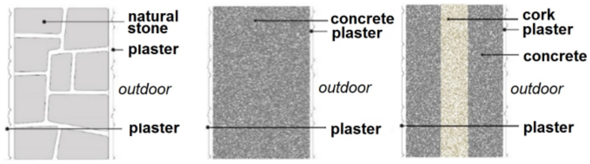

Fig. 8: Construction details of the stratigraphy: building age A (1950), B (1970), C (1980).

The energy demand outcomes with the different envelope definitions are compared in Fig 9. The New MP scenario results consider the Building 3 in the future urban development with the actual envelope (A). The heating demand is well prevailing in comparison with the cooling need. In the new scenario, with a denser urban contest, the heating demand increases by about 8.5% in comparison with case A and 20% referred to case C (in case B is almost the same).

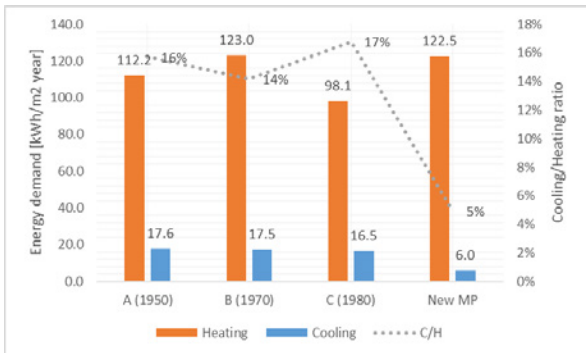

Fig. 9: Energy demand [kWh/m² year] for different envelope options and the New MP and cooling/heating demand ratio [%].

The cooling demand shows stronger variations decreasing by 65% with the urban densification. Nevertheless, the energy need in summer with the New MP is 5% of the winter energy need whereas in the existing scenario the average ratio between cooling and heating demand is 16%. Therefore, the urban densification reducing the solar energy incoming in the building can be favourable in

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_37, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

reducing cooling needs, however, the main item in energy consumption of old and historical buildings is evidently the heating demand due to the poor when existing insulation and high thermal mass of the envelope. Furthermore, the window to wall ratio in these buildings is rather limited (30%) however the incidence of solar energy in summer is relevant.

4 DISCUSSION

As stated in this research project, urban planning strategies determine the possibility to exploit solar irradiation as solar passive/active, daylighting, human comfort, etc., factors that could be compromised during urban transformation. As outcome of this analysis, it has been found that street profiles significantly change in the new configuration of the Master Plan affecting solar radiation availability, human comfort and energy performances in pre-existing buildings (focusing this study in protected buildings in the area).

5 CONCLUSIONS

The proposed methodology reached the project such as to properly assess how urban densification policies influence the energy performance, the conservation level and the solar availability of pre-existing buildings focusing mainly on the major impacts over the protected cultural heritage, undergoing transformations of the surrounding environment. This project put a special emphasis on important issues at the time of redefinition of an urban area have implications on historical but also on new buildings to be developed in the future considering the solar active installations that should be integrated to provide energy. Urban environments can significantly vary from site to site, depending on latitude, distances between buildings and height. Therefore, detailed studies based on the shown methodology, are crucial to be adopted from site to site.

6 ACKNOWLEDGMENTS

This project was funded by the Stiftung zur Förderung der Denkmalpflege (Foundation for the Promotion of the Conservation of Historical Monuments).

7 REFERENCES

1. Skovbro, A. Urban Densification – A Sustainable Urban Policy? 2002, The Sustainable City II. Urban Regeneration and Sustainability. Edited By: Wessex Institute of Technology (UK), Universidad Complutense (ES) and James Cook University (AUS)
2. Compagnon, R., Solar and daylight availability in the urban fabric, Energy and Buildings 36, 2004: p. 321–328.
3. Dilllemuth A., Roos B. White D.Integrating Solar Energy into Local Development Regulations. Solar briefing papers. <www.planing.org/research/solar>
4. Dipartimento del territorio - Repubblica e Cantone Ticino, 2007, Piano direttore: obiettivi pianificatori. Switzerland
5. C. S. Polo López, et al. Urban densification and energy performance of existing buildings: a case study, in CISBAT Conference: Future Buildings and Districts. 2015: Lausanne, Switzerland. p. 943-948.
6. D.G. Steyn. The calculation of view factors from fisheye-lens photographs, Research note, Atmosphere-Ocean, 198018:3, 1990: p. 254-258.
7. Neila González J.. Arquitectura bioclimatica en un entorno sostenible. Ed. Munillaleria, 2004, p. 440
8. Poul O. Fanger: Thermal Comfort. Analysis and Applications in Environmental Engineering. Krieger, Malabar, Fla. 1982,
9. EPBD recast, Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings. Official Journal of the European Union
10. IEA SHC Task 40, Net Zero Energy Solar Buildings, Project duration: October 2008—September 2013.
11. Lobaccaro G., Frontini F. Solar Energy in urban environment: how urban densification effect existing building. Energy Procedia, V. 48; 2014: p.1559 – 1569
12. Bonomo P., De Bernardis P., PV integration in minor historical centers: proposal of guide criteria in post-earthquake reconstruction planning. Energy Procedia V.48; 2014: p 1549–1558
13. Aste, N., Compostella, J., Mazzon, M., "Comparative energy and economic performance analysis of an electrochromic window and automated external venetian blind", Energy Procedia V.30; 2012, 404 – 413
14. De Lieto Vollaro R., et al. Building energy performance analysis: A case study, Energy and Buildings, V.87, 2015, p 87–94

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_37, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html