# Urban densification and energy efficiency in Smart cities - the VerGe project (Switzerland)



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Abstract. The issues of building densification and land conservation are much debated in local development policies and are related to the rational use of local environmental and climate resources. The paper proposes a critical reading of the research project that ISAAC Institute of SUPSI University (Switzerland) carried out on these themes by analysing a case in the municipality of Lugano Paradiso. The project analyses the effect of the urban transformation in terms of energy and solar access. The proposal of the case study was aimed at highlighting the importance quantifying some of the important consequences of local planning strategies can have on energy and the environment so as to contribute to assess their impacts to meet sustainable criteria and possible improvement actions.

Keywords: Smart city, Building densification, Solar resource, Energy performance, Urban quality

## Introduction

A smart city copes with the energy issue in a comprehensive manner, through a programme, concrete actions and the coordination of all stakeholders. It is a city that considers energy as a crucial resource and plans its use according to objective evaluations. It is a city that helps citizens to be part of the change, informs them on what they can do to reduce their energy consumption, and launches initiatives leading to economic advantages. Furthermore, a smart city does not separate energy and urban planning, but rather manages the interactions between the various tools, fully aware that the quality of the urban environment determines a better microclimate in which buildings consume less (Giuliano Dall'O, 2014).

In terms of urban planning, there is a general consensus among the scientific community on the need for developing compact urban settlements (Camagni, 2002). The Aalborg Charter (May 1994) already recognized the importance of implementing effective policies in land use and planning, involving a strategic environmental assessment. The emphasis was put on the opportunities offered by dense urban concentrations to provide public transport services and more efficient energy supply. Further on, the Leipzig Charter and the Toledo Declaration, 2010, pointed to the need for integrated urban development policies, which could promote, among other things, the creation and consolidation of quality public spaces, by upgrading infrastructure networks and improving energy efficiency, as well as the development of efficient and affordable public transport systems.

Moreover, new urban regulations aim to limit the extension of urban sprawl promoting compact cities, similar in the spatial distribution to the historical city that for its intrinsic nature had a compact shape on a human scale. In the last twenty years, there has been increased interest in how the form of cities can contribute to their sustainability: the concept of "urban densification" has assumed the meaning of building volumes that are more compact and closer together, developing a sustainable urban planning model and preserving public spaces. Dense cities permit lower energy consumption per capita than more dispersed suburban equivalents (Lobaccaro, Frontini, 2014).

At the same time, European energy policies stress the importance of both increasing energy supply from renewable energy sources and reducing energy demand in the final consumption sectors, with a special emphasis on the building sector. In such a framework, political statements and directives, aimed at stronger integration between energy and building sector concerns, were developed[1] (Polo Lopez, Frontini, 2015).

The paper proposes a critical analysis of the VerGe research project (2015) that ISAAC (Institute for Applied Sustainability to the Built Environment), which is part of the University of Applied Sciences of Southern Switzerland (SUPSI), carried out on the issues of building densification related to the rational use of solar energy by analysing a case study in the area of Ticino, i.e., in the municipality of Lugano Paradiso (Switzerland), whose town centre is deeply changing towards a progressive urban densification, thanks to a new urban plan and zoning regulations.

The case study is aimed at highlighting the importance of quantifying the most important consequences that local planning strategies can have on energy and the environment sector, both considering quantitative and qualitative factors, so as to be able to assess impacts useful to define synergically sustainable criteria and possible improvement actions.

The paper is divided into three paragraphs: the first stresses how topical and urgent the energy issue is and, therefore, justifies the choice to critically analyse the case study, since the VerGe project can provide an effective scientific contribution to enhancing energy efficiency in smart cities; the second focuses on the case study critically analysing it and highlighting the originality of the methodology used by the research group; finally, the last paragraph deals with the research group's final observations on the results achieved, which have led to particularly interesting guidelines for town planners and authorities, who may apply them to urban transformation processes in different urban scenarios, always respecting local specific conditions

## Energy: a topical issue

Several European projects have already proposed innovative approaches to raise energy efficiency through urban development, the refurbishment of the building stock, and effective methods and tools able to evaluate solar energy aspects and support planning and design processes, which are still lacking or in a prototype stage; also a rich literature has been produced on this subject[2].

A good orientation of the building in the urban fabric does not ensure all the necessary hours of sunshine. In order to apply the rule of the "right to the sun", it is also fundamental to respect the



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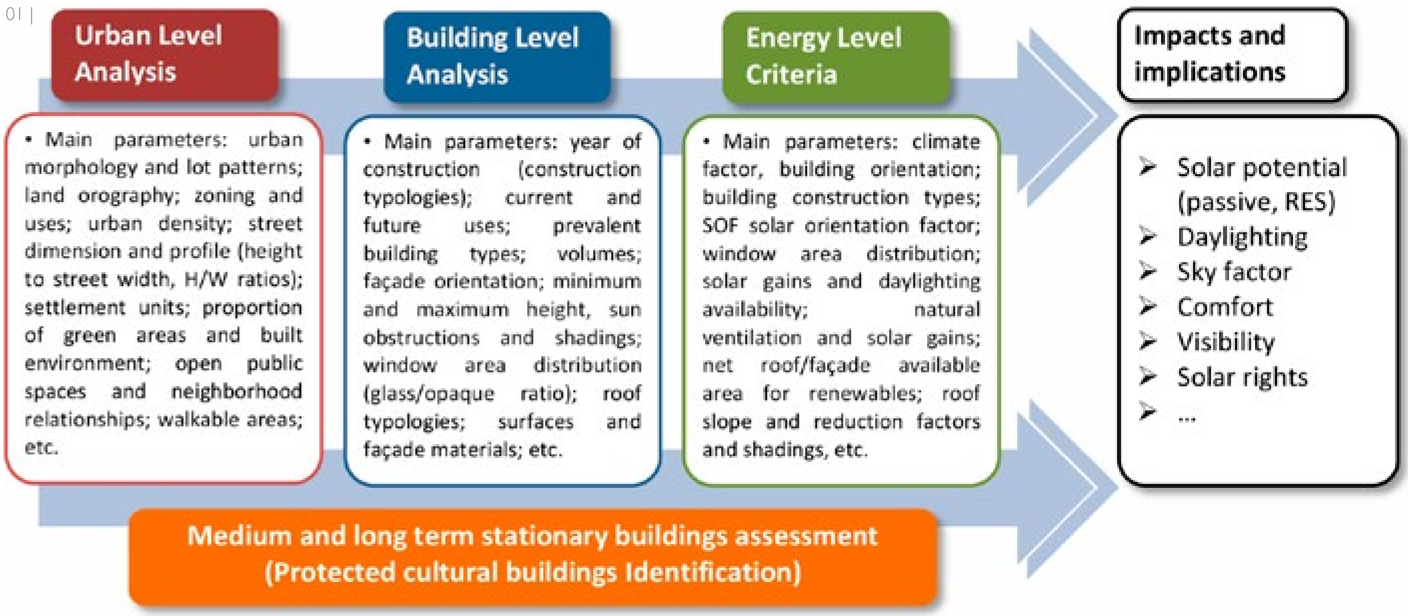


01 | Workflow diagram - methodology

right distances between buildings so that façades can receive the right amount of solar energy in winter. In the same way, factors, such as the geography and topography of a place, the type of vegetation or soil characteristics, and the built mass around the building, could affect not only the sun and daylight availability but also the local wind regime (wind speed and direction)[3].
Solar rights and solar access laws already define the proper configuration of buildings' shape, restricting the height of buildings depending on the width of the roads, in order to ensure correct sunlight and solar gain. However, past efforts were focused on single new buildings and, in particular, on a comprehensive understanding of the opportunities to exploit the sun in active and passive ways. The scientific community is, however, aware of the need to enlarge the scale of analysis and to move to urban planning and design scales. This would allow taking into account the buildings' shape, orientation and density, as well as detecting possible cumulative effects that could limit the access to sunlight or solar gains by changing the wind path and, consequently, the micro-climate, or reducing the possibility of equipping buildings with solar systems.
Moreover, the impact on solar energy availability in existing buildings (in particular historical buildings) during urban transformation is still not well understood and is a matter of research. That is why, recently, the International Energy Agency (IEA) has decided to set up a new working group on "Solar energy in urban planning" aimed at monitoring progresses in such issues. The report produced by the IEA "Illustrative Prospective of Solar Energy in urban Planning:Collection of International Case Studies" is a collection of 34 case studies - divided into new urban areas, existing urban areas, lanscapes - (IEA SHC TASK 51, 2017).
This is further evidence that the topics dealt with by the Verge research project, which is also the result of the scientific collaboration between the SUPSI University and the EIA, are extremely innovative.

**Methodology**

The Verge research project aimed to investigate how urban modifications, in particular, urban densification policies, could influence the energy demand, the conservation level and the solar availability of pre-existing buildings as well as the impact on the perception and visibility of the protected heritage. Based on this initial insight, the project aimed to recognize, understand and analyze different urban densification scenarios, considering the massing of the buildings and other aspects, like sky-view factors or solar radiation impact analysis, to examine if the urban pattern and the building design in the scenarios considered were suitable for the energy conservation behaviour of existing buildings.
Lugano Paradiso district is undergoing a very fast urban densification process changing its open urban sprawl into infill, with a

02 |


02 | Spatial urban planning:left picture sows the current situation and the right one represent the future Masterplan – Urban transformation in the city center of Paradiso

03 |

03 | City Center Area of paradise – current status and new status when New master Plan will be implemented

closed and compact urban fabric, as defined in the new Master Plan regulation. The new Master Plan of the area was published in May 2011 and endorsed by the State Council in June 2012[4].
To investigate the impact of urban densification on the energy behaviour of existing buildings, simulation and photographic diagnostic tools were used. The information analyzed provided basic design guidelines for urban planners or public and private institutions, responsible for the protection of cultural assets, with the purpose of seeking a new way to best utilize the methodology proposed considering solar access rights and becoming aware of the real problems caused by urban sprawl.

The research methodological process can be summarized as follow:

1. Identification of typical buildings (protected cultural monuments) already existing in the context of Lugano Paradiso.
2. Current and new urban transformation status analysis: Identification of the relevant parameters highly influenced by urban morphology (i.e. solar energy access, passive solar gain, daylight access, historical preservation and value, building consumption, visibility and view contact).
3. Development of different urban densification scenarios based on such parameters. Simulation tools were used in order to predict the dynamic effects of surface overshadowing at an urban scale. The two scenarios considered (the present and the future urban plan) allowed testing the urban planning solutions proposed in the master plan. Conflicts between existing buildings (in particular, protected heritage buildings) and the surrounding public urban areas were highlighted and a methodological evaluation process allowed understanding and assessing the urban densification impacts on the energy behaviour and conservation level of those buildings. In particular, such an assessment focused on the exploitation of sunlight and solar energy (both passive and active) in existing buildings and urban areas.
4. Definition of guidelines, recommendations and theoretical principles. Based on the results of the case-study, strategies able to favour effective integration and harmonization of conflicts were summarized and included at the end of the document. By doing so, the project transferred know-how and competences to municipalities.

The relevant parameters highly influenced by urban morphology, which affected energy aspects in buildings, were identified.
Different aspects and parameters linked to urban morphology and buildings typologies have a direct impact on building energy consumption, mainly on heating, cooling and ventilation performances: volumes, surfaces, streets width, façade orientation, sun obstructions and shading, etc. These key parameters allow establishing the “ideal” urban setting to reduce energy dependence on existing buildings and to improve the condition of stationary buildings in the area.
The main focus of the methodology proposed was to measure the impact and repercussions of urban changes on solar availability and their effects on the existing historical buildings and cultural monuments.
From the point of view of environmental impact, the densification process would be also a positive example of sustainability, if considering factors such as: the lower environmental impact due to greater exploitation of the soil and the minor use of free soil; the higher percentage of public spaces, and pedestrian areas; the decreases in car commuting by changing the urban mobility and urban accessibility, resulting in lower energy consumption,

04 | Process development scheme of Verge research - project

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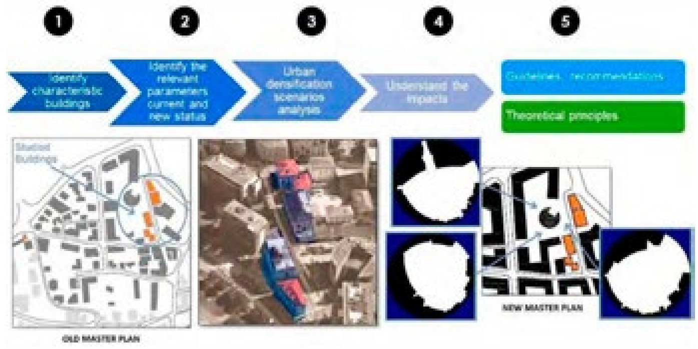


lower air pollution levels. The workflow (Fig. 1) shows that for each level of the chain, there are some important parameters that influence the energy aspects and energy balance of a building (consumption and production). At an urban level, specific urban planning significantly determines the possibility to relish solar irradiation in buildings. Solar energy exploitation on existing buildings (in particular, historical buildings) may be compromised during urban transformation. To shift the detail at a building level, always linked to the urban environment, it is necessary to examine the architectural situation already existing or under transformation. Thus, the distinctive elements of the surroundings were analysed taking into account building techniques, the year of construction, the materials used, the morphology of the buildings, and so on. Finally, all these aspects completed the assessment at an energy level. All levels have a direct impact on medium and long-term stationary buildings”[5].

It is important to underline how all the parameters taken into consideration in the urban and building level analysis affect not only the energy consumption and human comfort of a building but also the opportunity to generate energy with solar renewable resources.

The following aspects were identified as main parameters to evaluate such energy impacts (energy level): solar irradiation (solar passive strategies); sky factors modification in the urban context; human comfort; daylighting and illuminance levels; energy production and consumption (solar potential for renewable solar energy, energy efficiency of protected heritage buildings, solar rights assessment).

Simple and complex simulation analyses were performed to explain the effect of the densification process, which is taking place in Paradiso city center (CC) area, on each parameter mentioned above, and to provide the necessary background to suggest new approaches in urban planning that may guide future master plans.

**Conclusions**

Urban planning strategies determine the possibility to exploit solar irradiation for passive/active solar energy, daylighting, human comfort, etc., factors that may be compromised during urban transformation. In the same way, urban densification can influence the building energy demand and thermal performance, the level of conservation of existing buildings (in particular, of historical buildings) as well as the urban microclimate. Accurately quantifying these effects is a key factor for predicting reductions in solar availability, understanding their real impacts and detecting possible corrective measures.

The methodology proposed helped achieve the project goal, *i.e.* to assess properly how urban densification policies influence the energy demand, the conservation level and the solar availability of pre-existing buildings, focusing mainly on the major impacts over the protected cultural heritage, which should remain unaltered forever, while the surrounding environment is undergoing transformations.

At an urban level, streets and lots should be accurately oriented, for example, by placing buildings as close as possible to the northern boundary of the lot. At a building level, orientation, shape and height should be considered (e.g., buildings with a long axis should be oriented in order to reduce the shadow cast). Yet, the most interesting conclusion is the recognition of the key role urban planners and local authorities play in urban transformations. Urban planners write, amend, and administer standards, policies and incentives that have huge influences on the nature of changes, on the timing of future private development as well as on what, where and how local resources are used or protected.

Urban planners can set constraints, e.g., to ensure the unobstructed flow of solar energy through adjacent lots when the parceling and allotment of a particular urban area are designed. They also define ordinances specifying the standards for the exact size and location of the easement and indicating limitations on buildings or structures that could prevent the passage of light through it.

Specific ordinances on solar rights should ensure, as far as possible, daylighting and sun access on the south-facing wall of buildings during the hours of sunlight, keeping in mind latitude, topography, microclimate and the existing urbanization and vegetation, besides the uses and densities set up in the area.

The new Master Plans should consider establishing solar access standards for:

- the orientation of new roads and the lots;
- the location and height of new trees on public roads and other public properties;
- the intended use and the density of urbanization to conserve energy and/or facilitate the use of solar energy.

Communities can create incentives by streamlining the approval process, reducing authorization costs, and increasing flexibility for the integration of solar and local energy sources if all aspects are correctly considered since the first steps of urban codes.

It is important to develop also specific laws to eliminate uncertainty around where solar systems may or may not be allowed in order to ensure appropriate locations and mitigate any potential negative impacts.
Municipalities should attempt to provide basic zoning defining solar energy-related terms and determining whether solar energy systems are allowed for primary or accessory use in each zoning district.
Municipalities and urban planners should also tackle solar easement and access requirements as site planning guidelines for lot and building orientation profiles that maximize solar access, or think about easely comprehensible solar-ready development standards to be applied to buildings constructed to allow the future installation of solar energy systems.
The new ordinances should also address the PV system appearance, requiring neutral paint colors, specific forms and shapes according to the building envelope and BIPV systems, with non-active system components, customized for better and greater integration.
Finally, solar energy use, in all its forms, not only improves energy efficiency in buildings, but, since it is a renewable energy, it also fosters natural resources and reduces air pollution, greenhouse gas emissions, and dependence on fossil-fuel energy sources. In this perspective, the goal of the Verge project, fully achieved, is to demonstrate how researchers and urban planners can help municipalities to make the most of solar energy. Working together, they showed how local development regulations could support measures to better exploit solar and daylighting resources considering the peculiarities of the site and urban morphology.

## ACKNOWLEDGMENTS

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## NOTES

[1] See, for instance, the EU Directive on net energy zero buildings.

[2] Among others, the following publications are of particular interest: Amado M., Poggi F. (2012); Kanters J., Horvat M. (2012); Hanna T.P. (2016).

[3] For example, low speeds of 0.5 m/s could be problematic with cold winds, while speeds of 3 to 3.5 m/s would be desirable in hot and dry areas.

[4] Site Area: 240.000 sqm; Building Area: 330875 sqm; Area Density 1.38 inhabitant/sqm.

[5] Cfr. Polo Lopez C.S. and Frontini F. (2015), *Städtische verdichtung und energie verhalten der bestehenden gebäude - Verge project*, SUPSI, Lugano-Canobbio.

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