# The energy performance evaluation of buildings in an evolving built environment: an operative methodology

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**Abstract**

The paper is based on a case study in Switzerland, the Cantonal Director Plan, expected for the next years, which will change the urban density. The plan allows raising from three to four floors the high of the existing buildings now separated by not too wide streets, to get over up to eight floors, without modifying the width of street layout. A case study located in Paradiso municipality, part of Lugano's city (CH) is used to understand and quantify the impact of the future buildings on the historical heritage energy performance.


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## 1. Introduction

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 [1].

The nZEB [2] design is based on specified energy behavior of the building considering the input data as stated and unchangeable during the life of the building. The balance between energy consumption and production can be defined referred to a static condition although a constant context and building conditions are a strong simplified scenario working just for a limited life span. The possible change of building performance during the time and the variation of the urban context around a case study building can show immediately how a static value providing an energy label for the building has an expiration date.

Urban densification is a growing phenomenon that is strongly affecting the existing buildings thermal and energetically behavior [3]. The paper is based on a case study in Switzerland, where Cantonal Director Plan, expected for the next years, will change the urban density of the city [4]. The plan allows raising from three to four floors the height of the existing buildings now separated by not too wide streets, to get over up to eight floors, without modifying the width of street layout [5].

Dense and compact urban settlements provide a complex environment, where solar access and daylight availability can become a scarce commodity with also implications in the urban microclimate. The need to accurately quantifying these effects is a key factor for predicting reductions in solar availability or daylighting.

In this development process, special cases are the cultural protected monuments, unchanged and immutable through time, protected by the regulatory plans and bound by preservation needs and constraints that cannot benefit

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from a rapid urban development [6]. At this point, it is necessary to wonder for the impact of this urban transformation and about the real influence on building energy aspects (especially historical heritage) and their surrounding micro-climate. Moreover the impact on solar energy availability on existing buildings (in particular historical buildings) during urban transformation is still not well understood and is a matter of research.

This case study located in Paradiso municipality, part of Lugano's city (CH), is used to understand and quantify the energy impact of the future buildings on the existing protected building in the area, and part of a larger study that analyzes these matter [7].

## 2. Objectives and method

The study refers to the analysis of a particular building, Palace G. Guisan Street (A4907) (show in Figure 1), because it will be the most influenced by the building of the new plan.

The building under study was built between the end of sec. nineteenth and early twentieth centuries. The primarily use is residential and the total gross floor area floor (GFA) amount at 1515,55 m². It develops symmetrically around a stairwell unheated; it houses a pharmacy on the ground floor and the upper floors host apartments.

The building is oriented almost exactly north-south but tilted slightly to the west (of less than 10°).Today the building is closed between narrow streets and buildings to the south and east while to the north and west remains open to a public space. It is developed over three floors plus a very simple roof with four slopes inclined and unheated; there is an unheated basement accessible through the central stairwell, also without heating. It has several openings on all fronts and the main entrances are located across the main street (east), Guisan Street. The windows are small only occupying almost the 30% of the gross area of the façades. The back facade of the building overlooks a public square in the western side that is now under construction following the directives of the new urban plan.

The analysis has been performed with an energy simulation plug-in “BESTenergy” developed by the Politecnico di Milano. The plug-in works with SketchUp and allows to intuitively performing detailed and complex dynamic simulations of energy performance of buildings with EnergyPlus software [8].

The configuration of the building is defined thanks to a three-dimensional geometric modeler, allowing setting the thermo-physical properties of the all components of building envelope. The software enables a detailed verification of the real behavior of the building in terms of energy flows, requirements, consumption and comfort.

This building has been chosen for a more detailed analysis because it is one of those who undergo the biggest influence of new buildings. During the analysis was important to differentiate the levels, to see how the energy demand of the floors are altered differently.

**a.** **b.**

Fig. 1. Palace G. Guisan Street (A4907). East (a) and West (b) facades.

The first step was to create a 3D building with constructive details of the envelope, and a model of the area, made up of existing buildings, designed as shading surfaces, recognized by the program [9].

Two different simulations have been carried out: the first with the building in the current context and the second with the building in the hypothetical future context. The goal is to quantify the damage in term of energy demand brought by the new building configuration [10].

**a.** **b.**

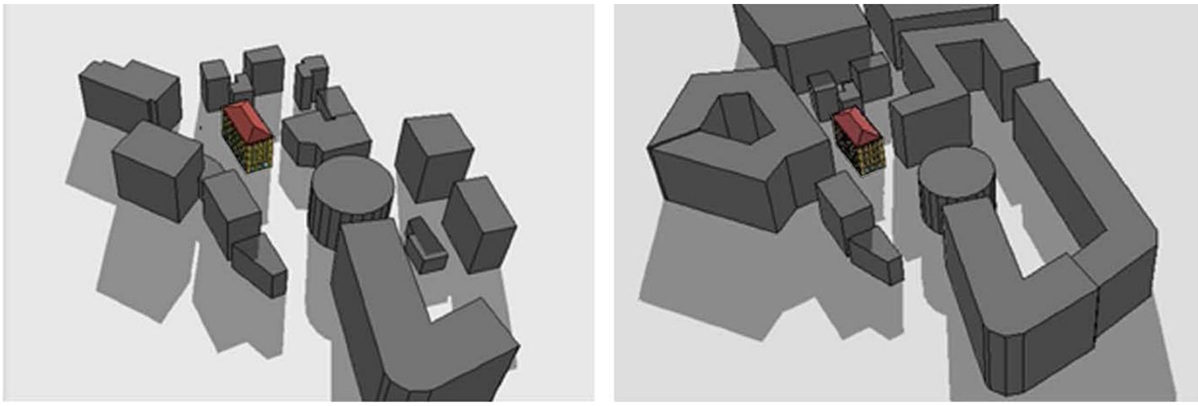

Fig. 2. Comparison between the models describing the existing situation (a) and new urban configuration (b).

## 3. Dynamic urban simulation

The calculations have been based on a visual survey on site and considering the layers of the building envelope compatible with the age of the building [12] and its constructional technology. The building envelope has been assumed as shown in figure 3 and composed by the following materials: 1,5 cm of plaster outside, internal layer of 40 cm of mixed rock without insulation and 1,5 cm of plaster inside the spaces of the building.

Both simulation, for the actual status and the future status when the new master plan will change the urban morphology of the surrounding areas, were run with the original 50s construction envelope details, no changes in the envelope have been considered.

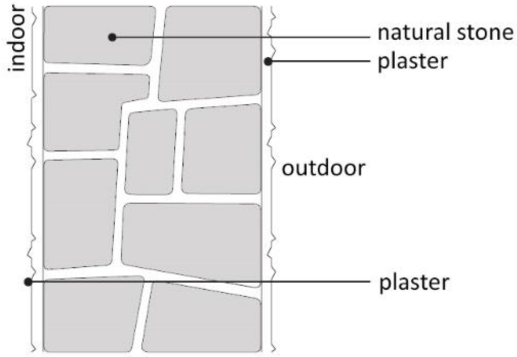


Fig. 3. Construction detail of the stratigraphy of the building package of the facade.

The roof is made of wood, and has a thickness ranging from 20 to 30 centimeters. The slabs of each floor are made with beams and wood paneling too. A windows transmittance value of 5 W/m²K, has been assumed, and an overall buildings performance, corresponding the same year of construction and considering the typological characteristics of this period, is about 166 kWh/m²yr. The simulations verified this value has assumed for the actual situation.

The results of the simulation are reported as heating and cooling demand for each floor level, such as to allow the direct evaluation of the different losses of performance in the different season during the year.

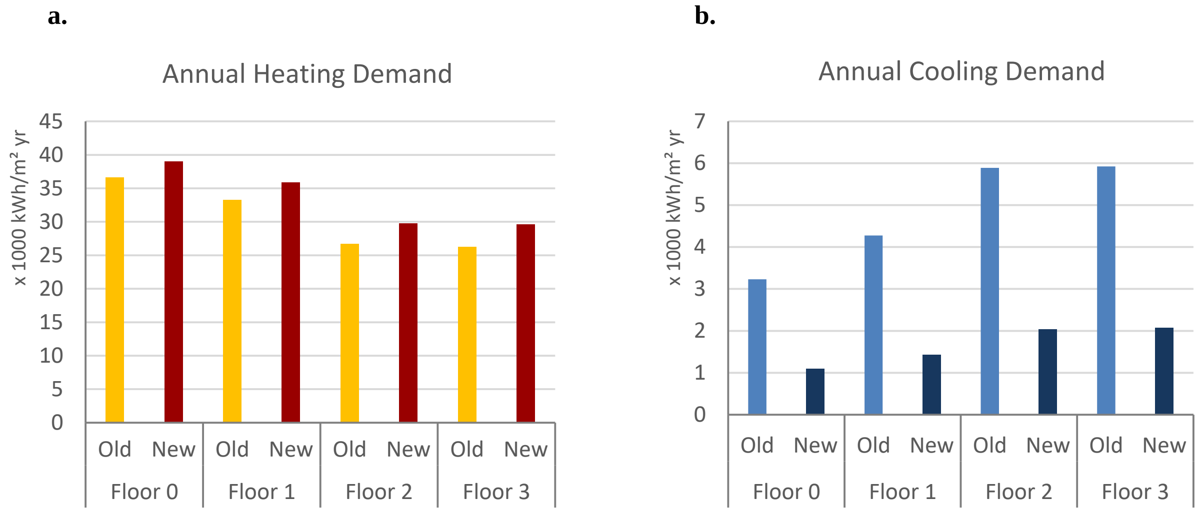


Fig. 4. Energy demand analysis: (a) red bars in the left graphic represent the annual building heating energy demand in winter season, differentiated by color intensities for the actual situation and future situation; (b) In the same way, the blue bars in the right graphic represents the annual building cooling energy demand in summer season, also for the actual and future scenario.

The climate of Paradiso is characterized by warm temperatures in summer time, so the energy savings are substantial.

Figure 4 shows the results of the simulations: during the winter, the energy needs for heating grow in the future scenario regarding the actual situation due to the reduction of solar radiation and the effect mutual shading of surrounding buildings that prevent sunlight and solar gains to the building analyzed (changes in the internal loads generated by artificial lighting are neglected). During the summer, the shadow cast by the new buildings expected by the new master plan and now under construction results in the reduction of the cooling demand.

## 4. Results

The results show how the situation changes during the year. During the winter, the energy demand is growing from the old to the new situation, in particular for the taller floors (second and third floors). Conversely, during the summer, the cooling energy necessary for the building falls: this is a consequence of the decrement of direct solar irradiance (Table 1).

Table 1. Total thermal energy demand during winter and summer in kWh/m² yr.

| kWh/m² yr | Actual scenario | Future scenario |
|---|---|---|
| Heating | 112,15 | 122,52 |
| Cooling | 17,72 | 6,04 |

Translating the calculated data to primary energy and dividing the results for the coefficients of performance, we can calculate the real expenses of the building [13]; for the heating the coefficient of performance assumed is 0,9; for the cooling the COP used is 3 (Table 2) [14].

Table 2. Total amount of primary energy consume during winter and summer in kWh/m² yr.

| kWh/m² yr | Actual scenario | Future scenario | Difference | % |
|---|---|---|---|---|
| Heating | 124,61 | 136,13 | 11,52 | 8,00% |
| Cooling | 5,87 | 2,01 | -3,86 | -66,00% |

The energy aspect analyzed previously is supported also by an economic analysis in order to estimate the economic damage and the costs due to the new interventions in the close built environment. Changes in energy behavior of the building have been calculated as a variation of the running cost on the case study building as consequences of a new urban configuration. The final step has been to economically quantify these extra energy demands on heating and cooling obtained in the yearly total energy consumption estimation. In this way it has been possible to calculate the effective economic damage brought by the new buildings in the future scenario when the new densification process in the urban area of Paradiso municipality will be completed [15].

The costs assumed are: 1,20 €/ m³ of methane for the heating boiler, which produces 9.593 kWh, and 0,06 €/kWh of electricity used for cooling purposes (Table 3) [16].

Table 3. Economic damage estimation (*prices references November 2015).

| €/yr | Actual | Future | Difference | % |
|---|---|---|---|---|
| Heating | 17.072,00 | 18.650,00 | 1.579,00 | 8,50% |
| Cooling | 386,00 | 132,00 | -254,00 | -65,70% |
| Total | 17.458,00 | 18.783,00 | 1.325,00 | 7,10% |

## 5. Conclusion

In conclusion, we can affirm that the total operational cost of the energy systems of the building increase by 7,10%, that implies an extra cost of about € 1.300/year. The influence of new constructions around the building considered in the analysis increases the energy consumption. In a different geographical location (with more severe climatic conditions, for example), with different building orientation layouts, or with higher ratio between opaque surfaces and transparent surfaces (e.g. medium ratio or larger), the damage would be certainly higher. There are also some special conditions on this case of study that must be noticed:

- The building is not well-oriented; there is not an optimal facade exposition also to minimize thermal losses.
- The building is located in a climate characterized by mild summers; it means a greater need for adequate shading to avoid undesirable overheating in these periods and a major need for ventilation and cooling in summer. The existing balconies in the building along with the shading provided by the new buildings in the future scenario contribute in this case in a positive way.
- The transparent surface area ratio of the building equals the 30% of the total opaque area of the building envelope; this ratio value is very low, compared to the average, ensuring a low demand for air conditioning in summer. Moreover, the high thermal inertia of the building envelope contributes in a positive way stabilizing indoor temperatures in summer. The absence of insulation by contrast rather enhances the negative effect in the case of winter.

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